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DEVELOPMENT OF TEST-ANALYSIS MODELS (TAM) FOR CORRELATION OF DYNAMIC TEST AND ANALYSIS RESULTS

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TEST-ANALYSIS MODEL (TAM) CREATION AND VERIFICATION PROCESS

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1. Introduction

The primary objective of structural analysis for aerospace applications is to obtain a verified finite element model (FEM). The verified FEM can be then used to perform loads analysis, evaluate structural modifications or design control systems. The most general approach to obtain a verified FEM involves testing a structure to create a "test model", then, correlating the test and finite element models to assess the fidelity of the FEM representation. If necessary, an update of the finite element model to better represent the test model can be performed. In this paper only the correlation of test and finite element models will be addressed.

The test-analysis correlation involves comparison of structural and modal properties derived from the test and finite element models. Since the number of Degrees-Of-Freedom (DOF) in the FEM is usually much larger than the number of DOF measured in the test, there is a need to adopt one of the following two approaches:

- 1) reduce the finite element model to the size of test model, or
- 2) expand the test mode shapes to the size of the FEM mode shapes.

A reduced finite element model with the same DOF as the test model, is called a Test-Analysis Model (TAM). In addition to providing a one-to-one basis correlation of analysis and test data, there are several reasons for developing a reduced TAM as opposed to expanding the test mode shapes. For example, reduced models have a smaller number of DOF and are, therefore, easier to handle computationally. Also, pre-test analysis can be performed using the reduced model to select sensor and excitation locations for the test. The relationships among the FEM, the TAM, and the test model concepts are shown in Figure 1.

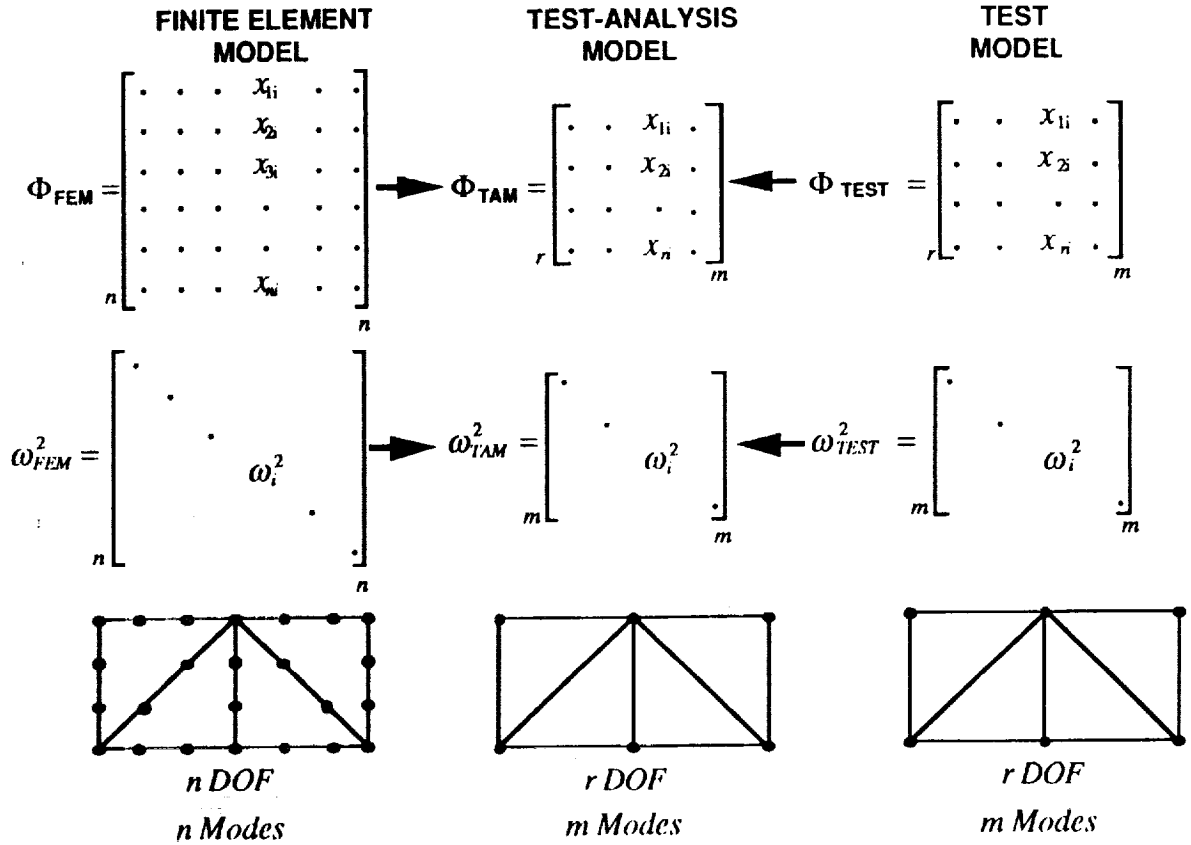


Figure 1. - Test/analysis model concepts.

A TAM must represent, as closely as possible, the dynamic characteristics of the FEM. To evaluate the fidelity of the FEM, the TAM modal parameters are compared with those measured in the test. The objective of this paper is to give a brief overview of the methods and procedures used to obtain the TAM and to correlate the modal parameters of the reduced systems to results obtained by both the FEM analysis and the test. First, a description of the characteristics of three reduction methods used to develop a TAM will be given. Some of the most common correlation criteria used to evaluate the accuracy of the TAM will then be described. Next, the procedures used for the creation and the verification of the different TAM's using MSC/NASTRAN will be described, along with a practical application on a laboratory truss structure. Finally, documentation on the availability of the software tools to create the TAM for each of the methods mentioned above will be presented.

2. Reduction methods

Several different reduction methods to create a TAM have been developed and reported in the literature [1-11]. A general classification that is often used, identifies two main groups, static and dynamic, depending on the kind of information used to develop the reduced model. The static methods utilize information directly from the FEM mass and stiffness matrices to develop the TAM, and, therefore, do not need any information from the eigenvalue solution of the FEM. The Guyan [1,2] and the Improved Reduced System (IRS) [3,4] reduction methods are included in this category. The dynamic methods, on the other hand, require knowledge of the eigenvalues/eigenvectors of the FEM to develop the TAM. The Dynamic [6,7,8], the Modal [9], the Hybrid [5], and the System Equivalent Reduction Expansion Process (SEREP) [10] formulations belong to this group.

To develop a TAM, reduced mass and stiffness matrices must be created (for simplicity damping is ignored). This is accomplished through the utilization of a transformation matrix, D , which relates the DOF retained in the analysis set to those DOF omitted. Each reduction method uses a different transformation matrix D , thus distributing the mass and stiffness information of the omitted DOF in different ways. However, the solution procedure for the reduced systems is identical for each method after D has been developed. This is illustrated in Figure 2, where the M_{FEM} and K_{FEM} are the $n \times n$ system mass and stiffness matrices respectively, M_{TAM} and K_{TAM} are the corresponding $r \times r$ matrices for the TAM, and U is a vector of physical DOF of length n or r .

FEM EQUATION OF MOTION:

$$M_{FEM} \ddot{U}_{FEM} + K_{FEM} U_{FEM} = 0$$

PARTITION FEM DOF

$$U_{FEM} = \begin{Bmatrix} U_{TAM} \\ U_o \end{Bmatrix} \quad K_{FEM} = \begin{bmatrix} K_{aa} & K_{ao} \\ K_{oa} & K_{oo} \end{bmatrix} \quad M_{FEM} = \begin{bmatrix} M_{aa} & M_{ao} \\ M_{oa} & M_{oo} \end{bmatrix}$$

RELATE OMITTED DOF TO TAM DOF

$$U_o = TU_{TAM}$$

DEVELOP TRANSFORMATION MATRIX FOR TAM

$$T = \begin{bmatrix} I \\ D \end{bmatrix} \quad U_{FEM} = TU_{TAM} \quad \begin{Bmatrix} U_{TAM} \\ U_o \end{Bmatrix} = \begin{bmatrix} I \\ D \end{bmatrix} U_{TAM}$$

CREATE TAM MATRICES

$$M_{TAM} = T^T M_{FEM} T = M_{aa} + D^T M_{oa} + M_{ao} D + D^T M_{oo} D$$

$$K_{TAM} = T^T K_{FEM} T = K_{aa} + D^T K_{oa} + K_{ao} D + D^T K_{oo} D$$

TAM EQUATION OF MOTION

$$M_{TAM} \ddot{U}_{TAM} + K_{TAM} U_{TAM} = 0$$

Note: a = TAM DOF
o = Omitted DOF

Figure 2 - Development of TAM from FEM.

Among the reduction methods previously described, this document will address three: the Guyan [1,2], the IRS [3,4], the Hybrid [5]. The following sections briefly describe each method, however, for an in-depth study of the mathematics of these methods and of other available reduction methods, the references [1-11] at the end of this document should be consulted.

2a. Guyan Reduction

The most commonly used static reduction method is the Guyan reduction. This method is attributed to Guyan (1965)[1] and Irons (1965)[2]. This formulation assumes that the displacements of the omitted DOF can be represented, in terms of DOF of the TAM, entirely by static information contained in the stiffness matrix. This is meant to preserve the strain energy distribution of the full system, thus yielding an exact reduction for statics. However, it neglects the inertial effects of the omitted DOF, thus it is only approximate for dynamics. Another simplifying assumption of this method is the fact that both the stiffness and the mass matrices use the same transformation. Nonetheless, the Guyan method is used extensively and is commonly found in finite element codes such as MSC/NASTRAN [11]. The reduction equations derived from Guyan are:

$$D_S = -K_{oo}^{-1} K_{oa}$$

$$K_{TAMS} = K_{aa} + K_{ao} D_S$$

$$M_{TAMS} = M_{aa} + M_{ao} D_S + D_S^T [M_{oa} + M_{oo} D_S]$$

where, D_S is the Guyan transformation matrix, and K_{TAMS} and M_{TAMS} are the reduced stiffness and mass matrices derived from using the Guyan reduction method.

2b. IRS Reduction

The Improved Reduced System (IRS) method is attributed to O'Callahan (1989) and was developed as an improvement over the Guyan method since it accounts for mass effects of the omitted DOF [3,4]. Essentially, the IRS method first uses Guyan reduction to develop an initial approximation of the reduced system, and then adds a correction factor to account for inertial effects of the omitted DOF. This method aims to preserve the strain and kinetic energy distribution of the full system. The following are the basic equations of the IRS method:

$$D_{IRS} = D_S + K_{oo}^{-1} [M_{oa} + M_{oo} D_S] M_{TAMS} K_{TAMS}$$

$$K_{TAM_{IRS}} = K_{aa} + D_{IRS}^T K_{oa} + K_{ao} D_{IRS} + D_{IRS}^T K_{oo} D_{IRS}$$

$$M_{TAM_{IRS}} = M_{aa} + M_{ao} D_{IRS} + D_{IRS}^T [M_{oa} + M_{oo} D_{IRS}]$$

where, D_{IRS} is the reduced IRS transformation matrix, $K_{TAM_{IRS}}$ and $M_{TAM_{IRS}}$ are the TAM stiffness and mass matrices of the IRS reduction method. Note that the IRS transformation matrix reduces to the Guyan transformation matrix when mass terms are neglected.

2c. Hybrid Reduction

The Hybrid method was developed by Kammer (1991)[5] as an improvement of the previously developed modal reduction method also by Kammer (1987)[9]. This method utilizes eigenvectors of the original FEM to create the transformation matrix. This reduced model represents exactly the eigenvalues/eigenvectors of the FEM for those modes that are included in the transformation matrix. Hence a drawback of this method is the eigensolution of the FEM must be known in advance. The characteristic equations of this method are:

$$D_H = D_S + [D_M - D_S] [\phi_a \ \phi_a^T \ M_M]$$

where

$$D_M = \phi_d [\phi_a^T \phi_a]^{-1} \phi_a^T$$

and,

$$M_M = M_{aa} + D_M^T M_{oa} + M_{ao} D_M + D_M^T M_{oo} D_M$$

from which:

$$K_{TAMH} = K_{aa} + D_H^T K_{oa} + K_{ao} D_H + D_H^T K_{oo} D_H$$

$$M_{TAMH} = M_{aa} + D_H^T M_{oa} + M_{ao} D_H + D_H^T M_{oo} D_H$$

where, D_H is the Hybrid transformation matrix, K_{TAMH} and M_{TAMH} are, respectively, the stiffness and the mass matrices (of dimension $r \times r$) for the Hybrid reduction method; ϕ_a and ϕ_o are the partitions of the FEM mode shapes corresponding to the TAM and omitted DOF.

3. Correlation Criteria

The correlation process involves a mathematical comparison of modal properties from the reduced models with those from the full FEM or from the tests. There are several parameters used for correlation [12,13,14]. Herein, four of these criteria have been selected for evaluation: 1) frequency error, 2) modal assurance criterion, 3) cross-orthogonality, and 4) orthogonality. In the following, these criteria are presented for the correlation of the FEM and the TAM models, however, they are also valid for correlating the TAM and the test models (in this case the subscript "FEM" should be replaced with "TEST").

(1) Percent frequency error, F_{error} , between the FEM and the TAM modes,

$$F_{error} = \left(\frac{F_{FEM} - F_{TAM}}{F_{FEM}} \right) \times 100\%$$

where,

F_{FEM} = FEM system mode frequency, (Hz)

F_{TAM} = TAM system mode frequency, (Hz)

The frequency error is a primary indicator used to establish the accuracy of the TAM in predicting the FEM system modes.

- (2) Modal Assurance Criterion (MAC): spatial correlation of the TAM mode shapes and the partitioned FEM mode shapes. From [15],

$$MAC = \sqrt{\frac{(\phi_{FEM}^T \phi_{TAM})^2}{(\phi_{FEM}^T \phi_{FEM})(\phi_{TAM}^T \phi_{TAM})}}$$

where,

ϕ_{FEM} = FEM mode shapes corresponding to the TAM DOF

ϕ_{TAM} = TAM mode shapes

The *MAC* is used to evaluate the similarity of the FEM and the TAM mode shapes. A *MAC* value of zero indicates that two modes are orthogonal, whereas a *MAC* value of one indicates that the mode shapes are identical within a scale factor.

- (3) Cross-orthogonality (XO) between the TAM modes and the FEM modes corresponding to the TAM DOF:

$$XO = \phi_{FEM}^T M_{TAM} \phi_{TAM}$$

where,

ϕ_{FEM} = FEM mode shapes corresponding to the TAM DOF

M_{TAM} = TAM mass matrix

ϕ_{TAM} = TAM mode shapes

The *XO* provides a mass weighted correlation of the TAM and the FEM mode shapes. This indicates whether the reduced system accurately predicts the shape of a mode as well as the relative motion of the various masses on the structure. The mass weighting is provided by the reduced TAM mass matrix, thus any errors due to the reduction process will be magnified since they will appear in both ϕ_{TAM} and M_{TAM} .

- (4) Orthogonality (ORTHO): provides a correlation of the partitioned FEM modes weighted by the TAM mass matrix. This indicates whether the FEM modes remain orthogonal with respect to the TAM mass matrix,

$$ORTHO = \phi_{FEM}^T M_{TAM} \phi_{FEM}$$

where,

$$\begin{aligned}\phi_{FEM} &= \text{FEM mode shapes corresponding to the TAM DOF} \\ M_{FEM} &= \text{TAM mass matrix}\end{aligned}$$

If the eigenvectors are normalized with respect to the full system mass matrix, the XO and ORTHO criteria should yield diagonal matrices with all diagonal elements equal to one. Accordingly, for the reduced system any deviation of the diagonal elements from unity indicates an inaccuracy resulting from the reduction process.

4. MSC/NASTRAN TAM Creation/Verification Process

The following paragraphs describe the implementation, in MSC/NASTRAN (V65C) of the creation and verification process of the TAM using the three reduction methods described previously. The process has been divided into a series of six steps which will be examined in detail one at a time. The NASTRAN model file for each reduction method includes several DMAP alters and instructions (for a non-superelement model). A complete listing of them can be found in Appendix II. Several utility programs are also available for post processing the intermediate and final results.

Each of the six steps, constituting the overall TAM creation/verification process, is briefly listed below, with a detailed explanation of each following.

- a) Determine the modal parameters of the structure by solving the FEM representation.

- b) Select the TAM DOF to be retained; create the TAM; and determine the modal parameters of the reduced model.
- c) Write the mass and mode shape matrices of the TAM.
- d) Partition the FEM mode shape matrix to match the degrees of freedom retained in the TAM.
- e) Perform correlation analysis between the modal parameters obtained from the TAM and from the FEM.
- f) Perform correlation analysis between the modal parameters obtained from the TAM and the Test model.

This process is described in detail in the flow chart included in Appendix I. Also included in Appendix I is a list of commands required to execute the various steps.

a) Solution of the FEM - (Solution 63 with Alter)

The first step of the TAM creation/verification process is to obtain the eigenvalue and eigenvector solution of the complete FEM (Solution 63 of MSC/NASTRAN 65C). The FEM mode shapes that result from this run must be stored in two NASTRAN files that are created by the DMAP alter **RF63D307.DAT**, which assigns the two OUTPUT2 files to units 11 and 12. The OUTPUT2 file assigned to unit 11 contains the mode shapes in the global coordinate system while unit 12 stores them in the displacement coordinate system. Upon successful completion of this run, the OUTPUT2 file assigned to unit 12 must be converted to an OUTPUT4 file format for latter use in step d (note: the TAM derived from the Hybrid reduction does not require the execution of steps c, d, and e because the alter for step b computes the correlation matrices directly). The utility program that converts the NASTRAN OUTPUT2 file to an OUTPUT4 file format is **SEMCOMB**, which also combines the mode shape coefficients into a single set.

b) Creation and solution of the TAM - (Solution 63 with Alter)

In order to create and solve the TAM, the retained DOF must first be identified and then specified using ASET cards in the NASTRAN bulk data deck. The same ASET cards can be used independent of the reduction method employed. Since the default reduction method in NASTRAN is Guyan, the specification of TAM DOF on the ASET cards along with the Solution 63 run is all that is needed to create and solve the Guyan-reduced model. The IRS and the Hybrid reduction methods require the **IRSRED63.ALT** alter, and the **HRED63.ALT** alter, respectively for Solution 63. Since the Hybrid method utilizes the FEM mode shapes to create the transformation matrix, the FEM mode shapes computed as part of step a must also be included in this process. These mode shapes are stored in an OUTPUT4 file that is assigned to unit 11. The OUTPUT4 mode shape file is available as the result of running the **SEMCOMB** utility program mentioned in step a. As mentioned above in the case of Hybrid TAM all the required mass and mode shape matrices are already available, therefore the correlation analysis is performed as part of step b.

c) Write the TAM mass and mode shape matrices - (DMAP)

Upon successful completion of the TAM solution, the TAM mass and mode shape matrices are extracted from the NASTRAN database (created in step b) and stored in utility files to perform the correlation analysis. Once the **WTTAM.DMP** DMAP has been executed, these matrices will be retrieved and stored in two OUTPUT4 files. The mass matrix is stored in the file assigned to unit 11, while the mode shapes are stored in the file assigned to unit 12. As previously explained this step does not apply to the TAM obtained from the Hybrid reduction method.

d) Partition FEM mass and mode shape matrices - (DMAP)

The partitioning of the original FEM mode shape matrix to include only the DOF of the TAM is necessary for the correlation analysis of the next two steps. This is

performed running the **PARTNMODX.DMP** NASTRAN DMAP instruction set. This DMAP sequence operates on the mode shapes of the original FEM by selecting the TAM DOF previously chosen in the original FEM bulk data using the ASET cards. The original FEM mode shapes are stored in the OUTPUT4 file assigned to unit 11 that was created in step a as the result of running the **SEMCOMB** program. The partitioned FEM mode shapes are stored in OUTPUT4 file format in the file assigned to unit 12. As for the preceding step neither does this one have to be applied to the TAM obtained from the Hybrid reduction method.

**e) Correlation between modal parameters of the TAM and the FEM
- (DMAP and FORTRAN program)**

This step requires as an input the TAM mass and mode shape matrices and the partitioned FEM mode shape matrices. The **CORL8X.DMP** NASTRAN DMAP sequence computes the Modal Assurance Criterion (MAC), the cross-orthogonality, and the orthogonality matrices used in the correlation. Upon successful completion of the correlation run the NASTRAN output results can be reformatted with the **NASTABLE** utility program for a more acceptable appearance. Also the correlation analysis associated with the Hybrid TAM, performed as part of the solution of step b can be given a more readable format with the **NASTABLE** utility program.

**f) Correlation between modal parameters of the TAM and the test
model - (DMAP and FORTRAN program)**

The correlation of the TAM and test models is the same as the correlation of the TAM and the FEM with one exception: the partitioned FEM mode shapes are replaced by the test mode shapes. Therefore, a NASTRAN OUTPUT4 file that contains the test mode shapes must be created. First, the test mode shapes must be stored in an SDRC Universal file [16] named **TEST_ORIG.UNV**. Then an ASCII file (called **UNVRNM.INP**), that shows the relationship between the test GRID labels and analysis GRID labels, must be created. Each line of this file contains a test GRID label in column one followed by a space and the corresponding TAM GRID label in column two. If a corresponding TAM

GRID label does not exist, a value of -1 must be entered in the analysis column. The **UNVRNM.INP** file is used as an input file, together with the **TEST_ORIG.UNV** file, for the **UNVRNM** utility program. This utility program renames the GRID labels in the **TEST_ORIG.UNV** file, according to the relationship specified in **UNVRNM.INP**. The program also creates **TEST.UNV** a Universal file which contains test mode shapes whose DOF correspond to the TAM DOF.

Next, a file that contains the test DOF in NASTRAN Direct Matrix Input (DMI) format must be created by the utility program **UNVDMI**. The inputs required for **UNVDMI** are the test mode shapes, the coordinate systems, and the GRID label cards of the FEM (including the TAM DOF specified in the ASET cards). The test mode shapes are contained in the **TEST.UNV** file, while the coordinate and grid cards must be stored in a user-supplied file called **GRIDS.BLK**. The output file that contains the Direct Matrix Input data must be named **TEST.DMI**.

It is now possible to run NASTRAN so that the test DOF that are in Direct Matrix Input format are converted to an OUTPUT4 file. However, the NASTRAN input file must contain the DMAP instruction set **PHIATEST.DMP** along with the information in **TEST.DMI**. Also the NASTRAN database (TAM.D01), that was created as the result of the TAM solution run, must be assigned in this run to database file 2 (DB02). Upon completion of this run the test mode shapes are stored in an OUTPUT4 file called **TEST.OP4**. The last step, the correlation between the TAM and the test models, is performed following the same procedure described in step e with the changes listed below:

- 1) the test mode shapes must be normalized with respect to the TAM mass matrix (set param **normtest** to 1 in the bulk data cards),
- 2) the **TEST.OP4** (assigned to unit 13) must be substituted for the **FEM_PARTNA.OP4** file created above.

5. Case Study - Ten-bay Truss Structure

5.1 Truss structure description

In the following paragraphs a laboratory ten-bay truss structure is used as an example for the application of the test-analysis correlation process. This structure consists of ten, four-longeron truss bays, constructed of erectable aluminum joints and truss members. Various studies on this truss are being conducted in the Dynamic Scale Model Technology (DSMT) research program at NASA Langley Research Center where the structure was tested [17,18]. The ten-bay structure is cantilevered at one end and has two steel plates attached to the free end. Each bay of the truss is a cube with side dimensions of 1.64 feet. The total weight of the structure is 147.4 lbs including the weight of the end plates, 86.25 lbs. The structure that results possesses dynamic characteristics that represent those of a large space structure with low frequency, closely spaced modes and light damping. The first 9 modes of the structure, as predicted by analysis (see Figure 3), illustrate some of these features.

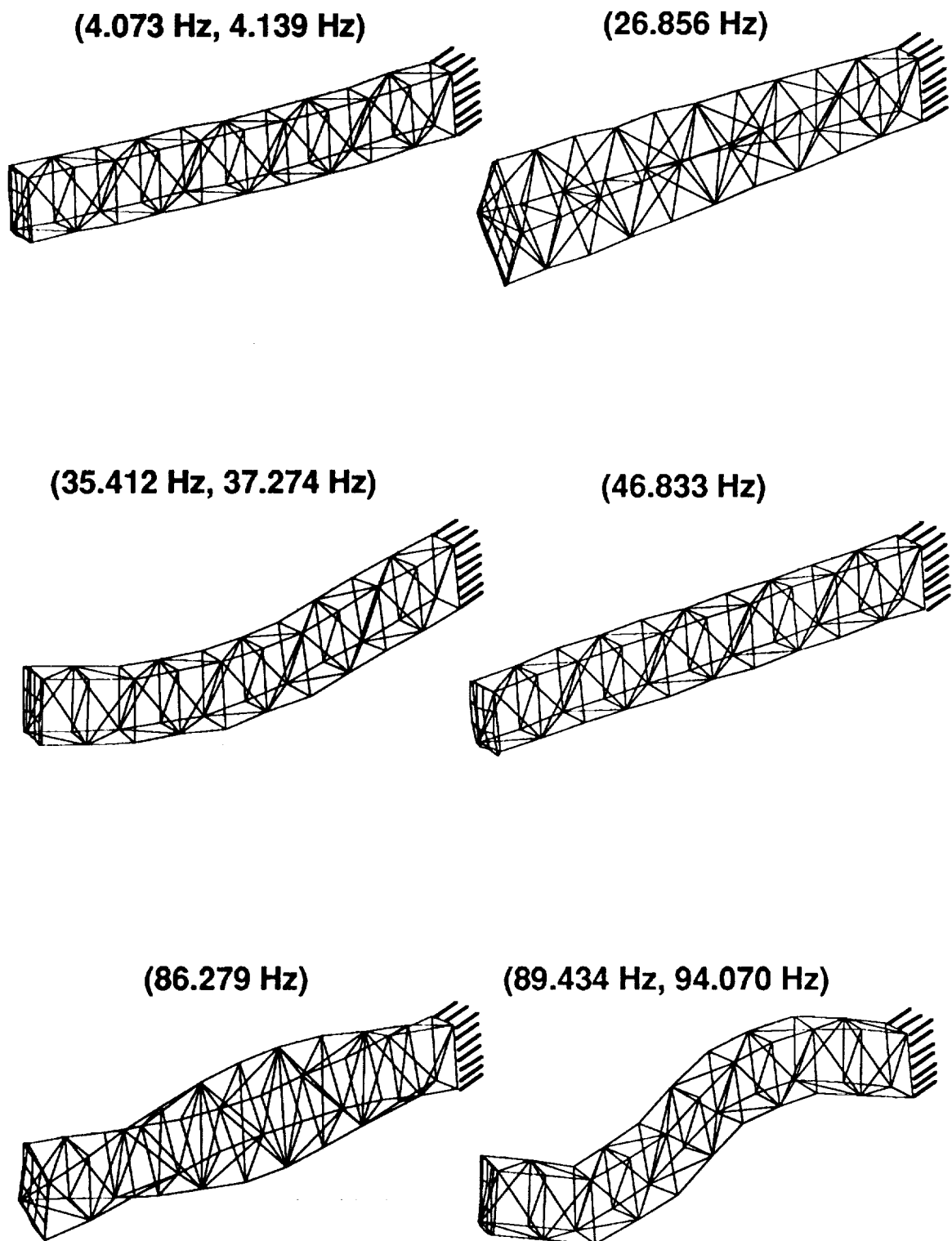
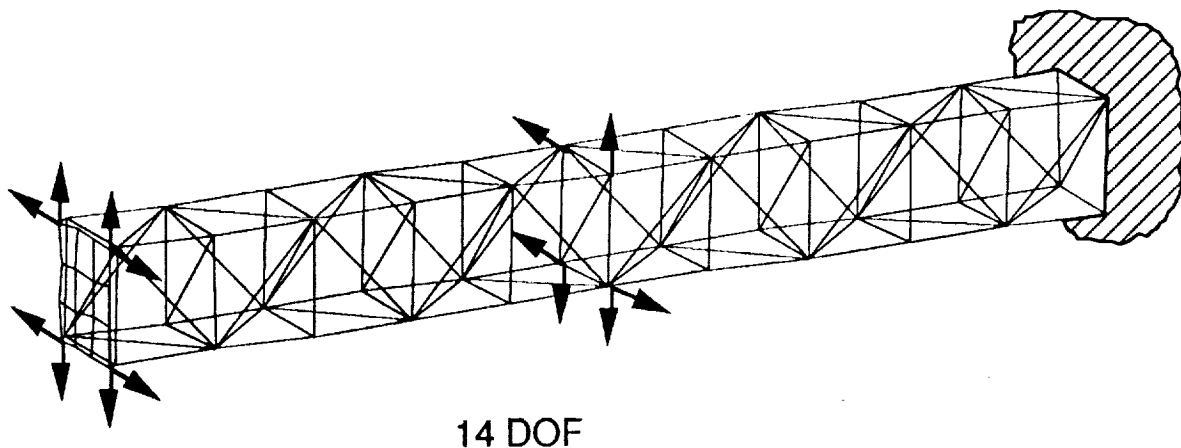


Figure 3. - Ten-bay truss modes.

5.2 Test-analysis correlation process

In this section the TAM creation/verification process for the ten-bay truss structure model will be presented for each of the three reduction methods described previously. The associated model files, procedures and special comments are documented for each of the steps and for each data file in Section 4. The listings of these data files for the ten-bay truss are contained in Appendix III. It should be noted that the associated data files were created for NASTRAN V65C running in a VAX/VMS environment.

In the example that will be illustrated, only 14 of 360 DOF of the complete FEM (see figure 4) were selected to represent the behavior of the whole structure. This choice was made to simulate the effects of an insufficiently instrumented structure such as a large space structure, which has a limited number of sensors due to cost or damage.



Note: FEM DOF = 360

Figure 4. - Ten-bay truss TAM DOF.

a) Solution of the FEM - (Solution 63 with Alter)

The complete listing of the NASTRAN input file for the ten-bay truss FEM (TENBAYFEM.DAT) is shown in Files 8 and 9 of Appendix III. File 8 contains the standard NASTRAN cards for the Executive, and Case Control, and File 9 contains the Bulk Data deck. A line-by-line description of the main additions and modifications required for File 8 are listed below:

Line 26 - The DMAP Alter **RF63D307.DAT** should replace line 26 of this file. These instructions are shown in File 1 of Appendix II.

Line 66 - The Bulk Data cards of File 9 should replace line 66.

The assignment file for this run (TENBAYFEM.COM) is shown in File 10 of Appendix III and the key instructions are listed below:

Line 4 - The database DB01 is assigned to file TENBAYFEM.D01.

Line 7 - FORTRAN unit 11 is assigned to file TENBAYFEM.U11, where the mode shapes in the basic coordinate system are stored in OUTPUT2 format. This file is not needed if you do not plan to use SDRG/IDEAS to plot mode shapes.

Line 10 - Likewise, unit 12 is assigned to file TENBAYFEM.U12 where the mode shapes in the displacement coordinate system are stored in OUTPUT2 format.

b) Creation and solution of the TAM - (Solution 63 with Alter)

The file that creates and solves the TAM has the same format as the file that solves the FEM. However, this NASTRAN model file, TENBAY14.DAT (File 11 of Appendix III) must include the following instructions that differ from those in the FEM data file described in the previous step.

Line 19 - This line must include the contents of the IRSRED63.ALT, this alter (File 2 of Appendix II) must be present only when using the IRS reduction.

Line 20 - The contents of HRED63.ALT (File 3 of Appendix II) must replace this line, only when the TAM is created with the Hybrid reduction method .

Line 62 - The bulk data cards of the ten-bay model should replace line 62. The bulk data cards of the FEM are shown in File 9 of Appendix III.

Line 68 - This line should be replaced by the contents of the ASET14.AST file (File 12 of Appendix III) in which the ASET cards that define the DOF retained in the TAM are listed.

File 13 of Appendix III contains the file assignment for this run (TENBAY14.COM).

Line 4 - The database DB01 is assigned to file TENBAY14.D01.

c) Write the TAM mass and mode shape matrices - (DMAP)

This DMAP extracts the mass and mode shape matrices of the ten-bay TAM from the NASTRAN database and writes them to OUTPUT4 files for the correlation analysis. The input NASTRAN file (WTTAM.DAT) is listed in File 14 of Appendix III and the following observations must be noted.

Line 17 - The DMAP instructions of WTTAM.DMP (File 4 of Appendix II) must replace this line.

Lines 28-39 - The parameters defined in these lines are necessary for this run.

File 15 of Appendix III shows the assignment file (WTTAM.COM), where:

Line 5 - The NASTRAN database file of step b (TENBAY14.D01) is identified as the database for this NASTRAN execution.

Line 9 - The OUTPUT4 file associated with unit 11 is assigned to the TAMMASS14.OP4 file. This file contains the TAM mass matrix in OUTPUT4 file format.

Line 13 - The OUTPUT4 file associated with unit 12 is assigned to the TAMMODES14.OP4 file. This file contains the TAM mode shape matrices in OUTPUT4 file format.

d) Partition FEM mass and mode shape matrices - (DMAP)

The following step partitions the FEM mode shapes to match the TAM DOF. The NASTRAN input file (PARTMODA14.DAT) for the execution of this procedure is shown in File 16 of Appendix III.

Line 16 - The PARTNMODX.DMP (File 5 of Appendix II) DMAP must replace this line.

Line 31 - The bulk data cards (File 9 of Appendix III) of the complete FEM must be present at this point .

Line 38 - The ASET cards (File 12 of Appendix III) defining the DOF to be retained in the TAM are required at this line.

The assignment file (PARTNMODA14.COM) for this run is shown in File 17 of Appendix III.

Line 4 - The OUTPUT4 file TENBAYFEM.OP4 that was created as the result of running the SEMCOMB utility program in step a is assigned to unit 11.

Line 7 - The partitioned FEM mode shapes are stored in the OUTPUT4 file (TENBAY14_PARTNA.OP4) associated with unit 12 of this run.

e) Correlation between modal parameters of the TAM and the FEM - (DMAP and FORTRAN program)

The correlation matrices between the TAM and the FEM models are computed using the NASTRAN input file CORL8TAM.DAT (File 18 of Appendix III) as follows:

Line 19 - The DMAP instructions associated with CORL8X.DMP must be on this line (File 6 of Appendix II).

Lines 30-40 - The parameters on these lines could be modified to execute or skip specific operations in the computation of the correlation matrices. The value of 1 indicates that the specific operation is to be performed, the value of -1 indicates that the specific operation should be skipped. When computing correlation matrices between the TAM and the FEM the following settings are recommended:

ORTHO = 1 CROSS = 1 MAC = 1 NORMTAM = -1 NORMTEST = -1

When computing correlation matrices between the TAM and the test model the following setting are recommended (note NORMTEST parameter):

ORTHO = 1 CROSS = 1 MAC = 1 NORMTAM = -1 NORMTEST = 1

See the CORL8X.DMP listing for a description of these parameters.

The assignment file (CORL8TAM14.COM, File 19 of Appendix III) contains the following instructions:

Line 5 - The OUTPUT4 file that contains the TAM mass matrix, created in step c, is assigned to unit 11 (TAMMASS14.OP4).

Line 9 - The OUTPUT4 file that contains the TAM mode shape matrices, also created in step c, is assigned to unit 12 (TAMMODES14.OP4).

Line 13 - The OUTPUT4 file that contains the partitioned FEM mode shapes, created in step d, is assigned to unit 13 (TENBAY14_PARTNA.OP4).

The output file of correlation analysis runs was processed through the NASTABLE utility program. Also, the correlation results from the Guyan, the IRS, and the Hybrid reduction methods were stored in the files called CORL8STAM.OUT, CORL8ITAM.OUT, and CORL8HTAM.OUT, respectively. These output files are shown in Files 20, 21, and 22 of Appendix III.

f) Correlation of TAM and test model - (DMAP and FORTRAN program)

In order to correlate the TAM and test model, the test mode shapes must be available in SDRC Universal file format. They are then converted to OUTPUT4 file format before computing the correlation matrices for the TAM and the test model. The TAM derived from the IRS method was chosen as a case study for the comparison with the test results, the correlation with the TAM derived from the other methods follows the same procedure.

File 23 of Appendix III shows a portion of the test mode shapes in the Universal file format (TEST_ORIG.UNV). Also, File 24 in Appendix III shows the content of the UNVRNM.INP file, which contains in the first column the grid labels associated with the test mode shapes and in the second column the grid labels as defined in the FEM. These files are required so that the UNVRNM utility program can match the test grid labels with those of the FEM. A portion of the modified test mode shape Universal file (TEST.UNV) is shown in File 25 of Appendix III. Since the FEM and test model of the ten-bay truss structure did not use different grid labels to represent the grids, the execution of the UNVRNM program was not necessary for this example.

The UNVDMI utility program is used to convert the test mode shapes to Direct Matrix Input format. This process requires the ten-bay bulk data cards to be stored under the filename GRIDS.BLK (File 26 of Appendix III). The test mode shapes in the Direct Matrix Input format were stored in TEST.DMI file a portion of which is shown in File 27.

The content of the TEST.DMI file along with the DMAP instructions PHIATEST.DMP (File 7 of Appendix II) were included in the NASTRAN run. The input file for this execution is shown in File 28 (PHIATEST.DAT) and the following items must be noted:

Line 13 - The DMAP instructions associated with PHIATEST.DMP should replace this line.

Line 27 - The content of TEST.DMI file should replace line 27.

The content of the PHIA TEST.COM file (File 29 in Appendix III) identifies the file assignments for this run and the following observations should be noted :

Line 3 - The NASTRAN database filename is identified at this line.

Line 6 - The TAM database filename (TAM.D01) that was created in step b is identified here. This database will have a 'read only' status (see line 1 of PHIA TEST.DAT).

Line 9 - The OUTPUT4 file that contains the test mode shapes is assigned to unit 11 (TEST.OP4).

Upon successful completion of the PHIA TEST run, the test mode shapes are stored in an OUTPUT4 file called TEST.OP4.

The next step is the computation of the correlation matrices between the TAM and the test model. The input file CORL8_TAM_TEST.DAT for this run is shown in File 30, and the file assignments are specified in the CORL8_TAM_TEST.COM file shown in File 31.

The output file of the correlation analysis run was processed through the NASTABLE utility program, and the results using the IRS reduction method are stored in the file called CORL8_I_TAM_TEST.OUT (File 32) .

5.3 Discussion of correlation results

a) Discussion of FEM-TAM correlation results

Assessing the quality of the correlation analysis is one of the most important phases of the test-analysis correlation process. The first step consists of comparing the frequencies predicted by the TAM with the system frequencies of the original FEM, as shown in Table 1. The next step is the computation of the correlation matrices, i.e., the modal assurance criterion, the cross-orthogonality,

and the orthogonality; these matrices are shown in Files 20, 21, and 22 of Appendix III respectively.

Table 1. - Comparison of TAM predicted frequencies.

Mode No.	FEM Freq (Hz)	Guyan Freq (Hz)	Guyan %Diff	IRS Freq (Hz)	IRS %Diff	Hybrid Freq (Hz)	Hybrid % Diff
1	4.073	4.073	0.000	4.073	0.000	4.073	0.000
2	4.139	4.139	0.000	4.139	0.000	4.138	-0.024
3	26.856	27.053	-0.734	26.857	0.004	26.857	0.004
4	35.412	36.603	-3.363	35.414	0.006	35.412	0.000
5	37.274	39.042	-4.743	37.278	0.011	37.274	0.000
6	46.833	*	*	46.962	0.275	46.834	0.002
7	86.279	94.782	-9.855	86.440	0.187	86.279	0.000
8	89.434	*	*	*	*	89.434	0.000
9	94.070	*	*	*	*	94.070	0.000

* - Did not predict the mode.

Ideally, the best correlation would yield a frequency difference of zero, and the normalized correlation matrices should be diagonal, have values of one on the main diagonal (in the ten-bay example the arbitrary value of 100 was chosen), and zero on the off-diagonals. Hence, the greater the deviation from these values the poorer the representation of the TAM. The frequency differences and the correlation matrices of the ten-bay example show clearly that the Guyan-derived TAM predicts only six of the first nine modes of the original FEM, and also, that the frequency errors increase for higher modes. In the IRS-derived TAM there is an improvement over Guyan since seven of the first nine modes of the original FEM are predicted, and the corresponding frequency error are much smaller. By definition, the Hybrid method-derived TAM predicts all the first nine modes exactly because these modes are used to create it. Note that, even though there are no axial degrees-of-freedom represented in the TAM models, the IRS and the Hybrid TAM still predict the axial mode (6th mode). This

phenomenon is due to the coupling between the axial and the transverse directions, and results in non-zero components for the axial mode.

b) Discussion of TAM-test correlation results

The IRS-TAM and the test mode frequencies and the corresponding frequency difference are shown in Table 2.

Table 2. - Comparison of the IRS TAM predicted frequencies with test frequencies.

Mode No.	TAM Freq (Hz)	Test Freq (Hz)	%Diff
1	4.073	3.91	4.002
2	4.139	3.98	3.841
3	26.857	25.78	4.010
4	35.414	35.37	0.124
5	37.278	37.00	0.746
6	46.962	45.72	2.645
7	86.440	88.92	-2.869
8	*	88.50	
9	*	92.50	

* - Did not predict the mode.

As indicated in this comparison of frequencies an acceptable correlation between the FEM and the test model can be noticed. However, the analysis of the correlation matrices (File 32 of Appendix III) shows that a good correlation exists only for the first 5 modes (the diagonal terms are 100 and almost all the off-diagonal terms are zero or approximating zero), while the other two modes that have been predicted, the 6th and the 7th, display different values from 100 on the diagonal and more non-zero terms on the off-diagonal. This reflects a poorer correlation between the IRS TAM and the test for these two modes. If a better representation of the FEM is needed the TAM should include a greater

number of DOF. But, if the FEM fails to represent accurately the test model the FEM must be updated first, in order to provide an accurate TAM.

6. Software location

The files listed in Appendix II and III are available on the Spacecraft Dynamics Branch IMAT cluster, in the IMATDIR directory, at Langley Research Center.

7. Summary

This paper describes the main features of three reduction methods and the correlation criteria used to evaluate the TAM accuracy. A major emphasis of the paper is a description of the procedures necessary for creation of the TAM and for correlation of the reduced models with the FEM or with the test results. Computational tools for the test-analysis correlation using MSC/NASTRAN are also described in the paper and made available for future reference and modification. Application of these tools is demonstrated with an experimental test configuration of a ten-bay cantilevered truss structure. Test-analysis correlation results are presented using the IRS reduction method.

8. References

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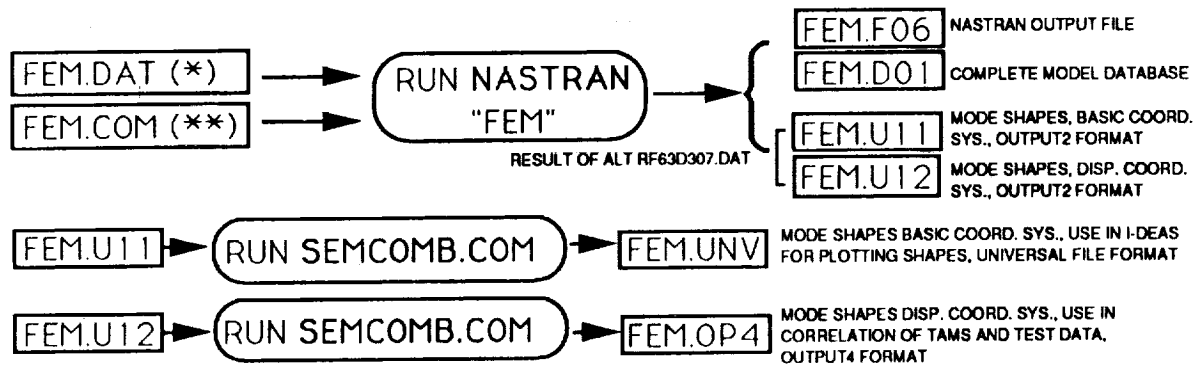
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Appendix I

Creation/verification process flow chart and list of commands

TEST ANALYSIS MODEL (TAM) CREATION/VERIFICATION PROCESS

STEP a - SOLVE COMPLETE FEM MODEL - (Solution 63 with Alter)



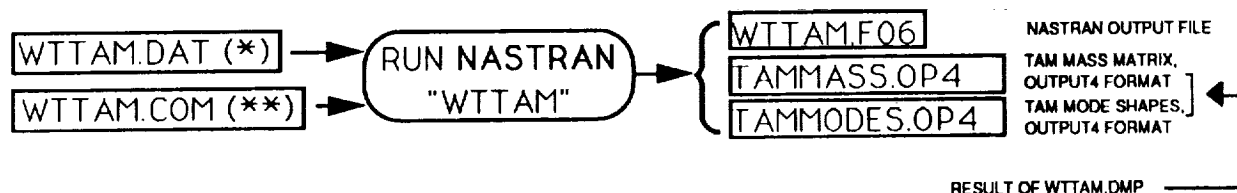
(*) MUST INCLUDE THE ALTER ALT RF63D307.DAT
 (**) ASSIGNS FEM.D01, FEM.U11 AND FEM.U12
 SEMCOMB PROGRAM = COMBINES THE SUPERELEMENT PLOTS.

STEP b - SOLVE TAM (REDUCED FEM) MODEL - (Solution 63 with Alter)



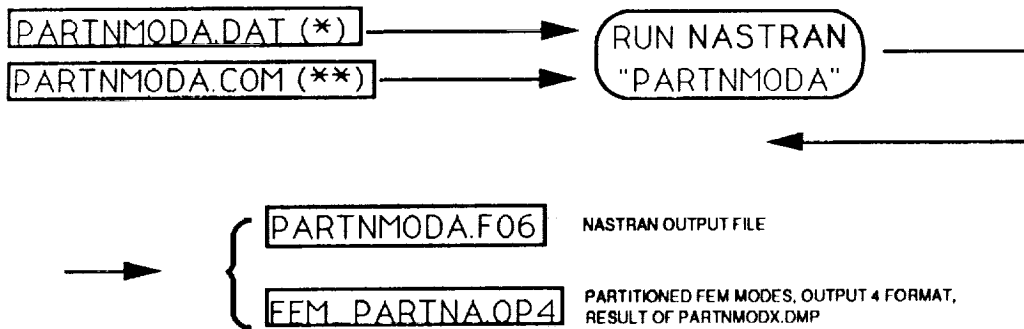
(*) MUST INCLUDE ASET AND BULK DATA, AND
 IF CREATING IRS INCLUDE IRSRED63.ALT;
 IF CREATING HYBRID INCLUDE HRED63.ALT (NO OTHER STEPS ARE
 NECESSARY FOR HYBRID; THE CORRELATION MATRICES ARE IN FILE TAM.F06)
 (**) ASSIGNS TAM.D01

STEP c - WRITE MASS & MODE SHAPE MATRICES OF TAM MODEL - (DMP)



(*) MUST INCLUDE THE DMAP WTTAM.DMP
 (**) ASSIGNS TAM.D01, TAMMASS.OP4 AND TAMMODES.OP4
 TAM DATABASE CREATED IN STEP 2 (TAM.D01) IS USED IN WTTAM RUN.

STEP d. PARTITIONING FEM MODE SHAPES TO TAM DOFS - (DMAP)

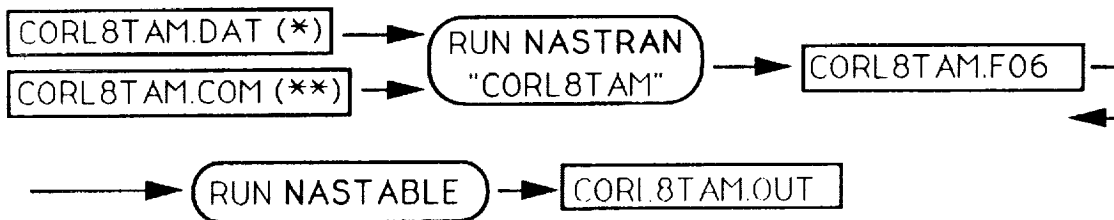


(*) MUST INCLUDE THE **ASET, BULK DATA** AND THE DMAP **PARTNMODX.DMP**

(**) ASSIGNS **FEM.OP4, FEM_PARTNA.OP4**

FEM.OP4 FILE (OUTPUT 4 FORMAT) GENERATED IN STEP 1 IS USED IN **PARTNMODA** RUN.

STEP e. CORRELATING TAM & FEM MODELS - (DMAP and FORTRAN program)



(*) MUST INCLUDE THE DMAP **CORL8X.DMP**.

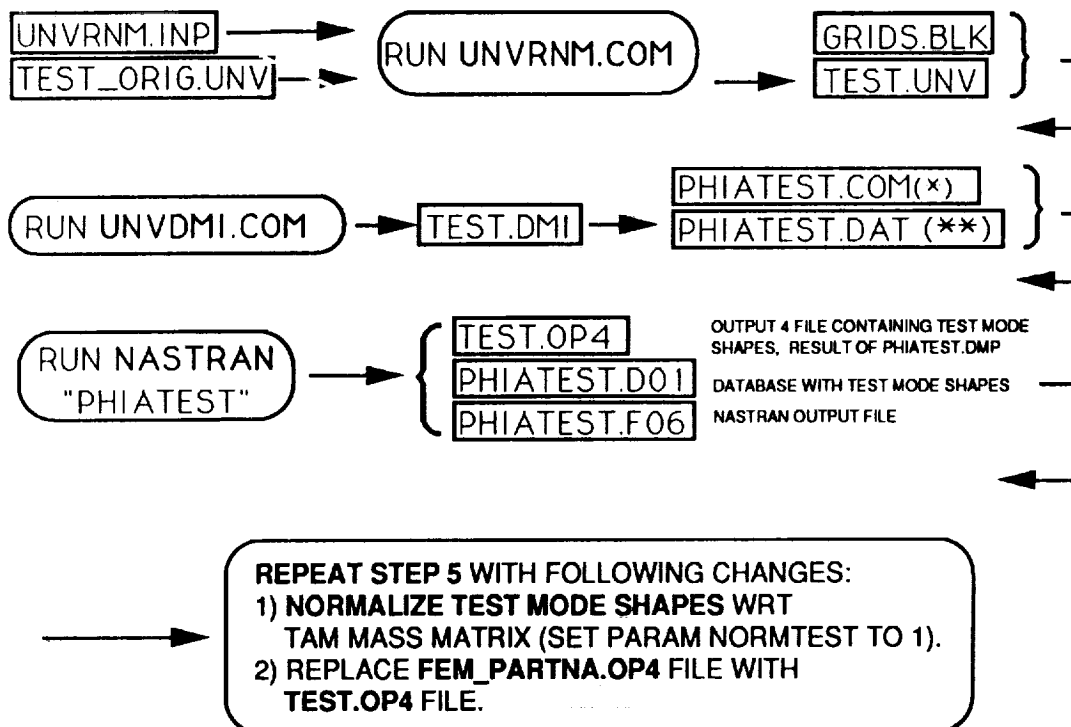
(**) ASSIGNS **TAMMASS.OP4, TAMMODES.OP4** AND **FEM_PARTNA.OP4**

MASS & MODE SHAPE MATRICES OF TAM MODEL (**TAMMASS.OP4** AND **TAMMODES.OP4**) FROM STEP 3 AND **PARTITIONED MODE SHAPES** OF COMPLETE MODEL (**FEM_PARTNA.OP4**) FROM STEP 4 ARE USED IN **CORL8TAM** RUN.

NASTABLE PROGRAM = REWRITES **ORTHO, X-ORTHO, AND MAC** MATRICES IN EASY TO READ FORMAT.

CORL8TAM.OUT FILE = CONTAINS THE **ORTHO, X-ORTHO, AND MAC** MATRICES.

STEP 1 - CORRELATING TAM & TEST MODELS - (DMAP and FORTRAN program)



(*) ASSIGNS TAM.D01 CREATED IN STEP 2

(**) MUST INCLUDE THE DMAP PHIA TEST.DMP AND THE TEST.DMI.

UNVRNM.INP FILE = TABLE OF CORRESPONDING TEST & TAM GRID POINT LABELS.

TEST_ORIG.UNV FILE = UNIVERSAL FILE OF MEASURED TEST MODE SHAPES.

PROGRAM UNVRNM = RENUMBERS TEST DOFS IN TEST_ORIG.UNV FILE TO TAM MODEL DOFS.

TEST.UNV FILE = UNIVERSAL FILE OF TEST MODE SHAPES WITH RENUMBERED DOFS.

PROGRAM UNVDMI = CREATES DIRECT MATRIX INPUT DATA FILE FROM TEST DOFS.

GRIDS.BLK FILE = NASTRAN GRID CARDS AND COORDINATE SYSTEMS.

TEST.DMI FILE = TEST DOFS IN DIRECT MATRIX INPUT FORMAT.

TEST.OP4 FILE = OUTPUT 4 FORMAT FILE CONTAINING TEST MODES.

List of commands.

Step a:

NASTRAN65 FEM.DAT	(CR)
SEMCOMB.COM	(CR)

Step b:

NASTRAN65 TAM.DAT	(CR)
-------------------	------

Step c:

NASTRAN65 WTTAM.DAT	(CR)
---------------------	------

Step d:

NASTRAN65 PARTNMODA.DAT	(CR)
-------------------------	------

Step e:

NASTRAN65 CORL8TAM.DAT	(CR)
------------------------	------

NASTABLE	(CR)
CORL8TAM.OUT	(CR)

Step f:

UNVRNM.COM	(CR)
UNVDMI.COM	(CR)
NASTRAN65 PHIATEST.DAT	(CR)

NASTABLE	(CR)
CORL8TAM_TEST.OUT	(CR)

Appendix II

Listing of DMAP alters and instructions

FILE 1. Listing of RF63D307.DAT

```
$ WRITE DEFLECTION DATA FOR PROCESSING BY PROGRAM SEMCOMB
$ -----
$ RIGID FORMAT 63 - NORMAL MODES ANALYSIS (SUPERELEMENTS)
$ MSC/NASTRAN VERSION 65
$
$ THIS ALTER WRITES DEFLECTION DATA TO TWO NASTRAN OUTPUT2 FILES
$ FOR PROCESSING BY PROGRAM SEMCOMB. PROGRAM SEMCOMB COMBINES
$ THE DEFLECTION SHAPES OF INDIVIDUAL SUPERELEMENTS INTO A SINGLE
$ UNIFIED DEFLECTION SHAPE.
$
$ THE DEFLECTION DATA IS WRITTEN TWICE TO TWO DIFFERENT OUTPUT2
$ FILES. THE DEFLECTIONS IN THE BASIC COORDINATE SYSTEM ARE WRITTEN
$ TO FORTRAN UNIT 11 (UT1), WHILE THE DEFLECTIONS IN THE DISPLACEMENT
$ COORDINATE SYSTEMS ARE WRITTEN TO FORTRAN UNIT 12. THE DEFLECTIONS
$ IN THE BASIC COORDINATE SYSTEM ARE SUITABLE FOR INPUT TO I-DEAS,
$ WHILE THE DEFLECTIONS IN THE DISPLACEMENT COORDINATE SYSTEMS ARE
$ PROPER FOR RE-INPUT TO NASTRAN.
$
$
$ SPECIAL INSTRUCTIONS TO USE THIS ALTER:
$ -----
$ JOB CONTROL LANGUAGE:
$ THE "UT1" AND "UT2" FILES MUST BE RETAINED AS PERMANENT FILES.
$ SEE THE MSC/NASTRAN APPLICATION MANUAL, VOLUME 2, SECTION 7.6,
$ FOR THE PROPER JOB CONTROL LANGUAGE FOR YOUR COMPUTER SYSTEM.
$ -----
$ EXECUTIVE CONTROL DECK:
$ SOL 63
$ INCLUDE THIS ALTER
$ -----
$ CASE CONTROL DECK:
$ THE CASE CONTROL DECK MUST INCLUDE STANDARD ANALYSIS REQUESTS
$ (SPC, ETC.). IN ADDITION, A REQUEST FOR DISPLACEMENT OUTPUT
$ (SUCH AS "DISP = ALL") IS REQUIRED.
$
$ THE DEGREES OF FREEDOM OUTPUT TO THE OUTPUT2 FILE MAY BE LIMITED
$ BY A SET AND A "PARTN =" COMMAND. OTHERWISE, ALL D-O-F OF THE
$ SUPERELEMENT ARE OUTPUT. SEE THE EXAMPLE INPUT DECK FOR MORE
$ INFORMATION.
$ -----
$ BULK DATA DECK:
$ REQUIRED PARAMETER CARDS FOR MIRROR- AND IDENTICAL-IMAGE
$ SUPERELEMENTS:
$
$ PARAM,GRIDINC SPECIFY GRID NUMBER INCREMENT ADDED TO
$ PRIMARY S.E. GRID NUMBERS TO FORM IMAGE S.E.
$ GRID NUMBERS
$
$ PARAM,SYMNORML FOR MIRROR-IMAGE SUPERELEMENT, SPECIFY THE
$ BASIC COORDINATE SYSTEM AXIS NORMAL TO THE
$ PLANE OF SYMMETRY (1, 2, OR 3).
$
$ FOR ROTATED IDENTICAL-IMAGE SUPERELEMENT,
$ SPECIFY THE BASIC COORDINATE SYSTEM AXIS
$ ABOUT WHICH THE ROTATION WILL BE PERFORMED
$ (1, 2, OR 3)
$
$ FOR IDENTICAL-IMAGE SUPERELEMENT WITHOUT
$ ROTATION, SPECIFY AS 0.
$
```

File 1.

\$ PARAM,ROTANGLE ROTATION ANGLE (DEGREES) FOR ROTATING AN
 \$ IDENTICAL-IMAGE SUPERELEMENT. MUST BE
 \$ SPECIFIED AS A REAL NUMBER WITH A DECIMAL
 \$ POINT. MUST BE SPECIFIED AS 0.0 FOR
 \$ MIRROR-IMAGE TRANSFORMATION.
 \$
 \$
 \$ OPTIONAL PARAMETER CARDS:
 \$
 \$ PARAM,NOBASIC,-1 SUPPRESSES OUTPUT OF RESULTS IN BASIC C.S.
 \$ (DEFAULT = 0 : DO OUTPUT BASIC C.S. RESULTS)
 \$
 \$ PARAM,NODISPL,-1 SUPPRESSES OUTPUT OF RESULTS IN DISPL. C.S.
 \$ (DEFAULT = 0 : DO OUTPUT DISPL. C.S. RESULTS)
 \$
 \$ PARAM,UTBASIC FORTRAN UNIT NUMBER FOR THE BASIC C.S. RESULTS
 \$ (DEFAULT = 11 : WRITE BASIC C.S. TO UNIT 11)
 \$
 \$ PARAM,UTDISPL FORTRAN UNIT NUMBER FOR THE DISPL. C.S. RESULTS
 \$ (DEFAULT = 12 : WRITE DISPL. C.S. TO UNIT 12)
 \$
 \$ PARAM,DATAREC,-1 SKIPS THE REMAINDER OF DATA RECOVERY OPERATIONS
 \$ AFTER RECOVERING DATA NEEDED FOR SEMCOMB
 \$ (DEFAULT = 0 : PERFORM STANDARD DATA RECOVERY)
 \$

 \$ EXAMPLE INPUT DECK:

\$ ID MODES,SPRELMT
 \$ SOL 63
 \$ TIME 10
 \$ DIAG 8,20
 \$
 \$. THIS ALTER
 \$
 \$ CEND
 \$ TITLE =SUPERELEMENT MODES ANALYSIS
 \$ \$
 \$ SEALL = ALL
 \$ \$
 \$ DYNRED = 50
 \$ METHOD = 50
 \$ \$
 \$ DISP(PLOT) = ALL
 \$ \$
 \$ SET 2 = 201 THRU 299
 \$ \$
 \$ SUBCASE 2
 \$ SUPER 2
 \$ LABEL = RIGHT WING
 \$ PARTN = 2
 \$ PARAM,GRIDINC,0 \$ NO GRID INCREMENT
 \$ SUBCASE 3
 \$ SUPER 3
 \$ LABEL = LEFT WING (MIRROR IMAGE OF RIGHT WING)
 \$ PARTN = 2
 \$ PARAM,GRIDINC,1000 \$ ADD 1000 TO S.E. 2 GRID NUMBERS
 \$ PARAM,SYMNORM,2 \$ Y AXIS IS NORMAL TO PLANE OF SYMMETRY
 \$ PARAM,ROTANGLE,0.0 \$ MIRROR IMAGE
 \$ SUBCASE 4
 \$ LABEL = VERTICAL TAIL
 \$ \$ KEEP ONLY POINTS ON THE SPARS
 \$ SET 4 = 401, 402, 403, 404, 491, 492, 493, 494
 \$ PARTN = 4

File 1. (cont.)

```

$ PARAM,GRIDINC,0 $ NO GRID INCREMENT
$ SUBCASE 1000
$ LABEL = RESIDUAL STRUCTURE
$ PARAM,GRIDINC,0 $ NO GRID INCREMENT
$ $ OUTPUT ALL RESIDUAL DOF - NO PARTN
$ BEGIN BULK
$ $
$ $ OUTPUT DATA ONLY IN THE BASIC COORDINATE SYSTEM
$ $
$ PARAM,NODISPL,-1
$ ENDDATA
$-----
$
$ DEFAULT VALUES
$
ALTER 1 $ AFTER BEGIN
PARAM //C,N,NOP/V,Y,DATAREC=0 $ DEFAULT - STND DATA REC
PARAM //C,N,NOP/V,Y,GRIDINC=0 $ DEFAULT - NO GRID INC
PARAM //C,N,NOP/V,Y,NOBASIC=0 $ DEFAULT - WRITE BASIC
PARAM //C,N,NOP/V,Y,NODISPL=0 $ DEFAULT - WRITE DISPL
PARAM //C,N,NOP/V,Y,SYMNORML=0 $ DEFAULT - NO SYMMETRY
PARAM //C,N,NOP/V,Y,UTBASIC=11 $ DEFAULT - BASIC = 11
PARAM //C,N,NOP/V,Y,UTDISPL=12 $ DEFAULT - DISPL = 12
PARAMR //C,N,NOP/V,Y,ROTANGLE=0.0 $ DEFAULT - NO ROTATION
$
$ WRITE MODAL FREQUENCIES
$
ALTER 849 $ V65 BEFORE SEDR LOOP
COND NOBASIC1,NOBASIC $ SKIP IF NO BASIC
OUTPUT2 LAMA//1/UTBASIC $ MODAL FREQUENCIES
LABEL NOBASIC1 $
$
COND NODISPL1,NODISPL $ SKIP IF NO DISPL
OUTPUT2 LAMA//1/UTDISPL $ MODAL FREQUENCIES
LABEL NODISPL1 $
$
$ DIVIDE GRID POINT INCREMENT INTO TWO NUMBERS
$
ALTER 962 $ V65 BEFORE SDR2
PARAM //C,N,DIV/V,N,GRIDINC1/GRIDINC/10000 $ TRUNCATE LAST 4 DIGITS
PARAM //C,N,MPY/V,N,GRIDINCX/GRIDINC1/10000 $ SHIFT LEFT 4 DIGITS
PARAM //C,N,SUB/V,Y,GRIDINC2/GRIDINC/GRIDINCX $ TRUNC. FIRST 4 DIGITS
$
$ DIVIDE THE ROTATION ANGLE INTO WHOLE DEGREES AND FRACTIONS
$ OF A DEGREE (NOTE: FRACTION LIMITED TO 4 DIGITS)
$
PARAMR //C,N,FIX/ROTANGLE/////V,N,ROTANGW $ WHOLE DEGREES (INTEGER)
PARAMR //C,N,FLOAT/V,N,ROTANG1/////ROTANGW $ CONVERT TO REAL NUMBER
PARAMR //C,N,SUB/V,N,ROTANG2/ROTANGLE/ROTANG1 $ FRACTION OF DEGREE
PARAMR //C,N,MPY/V,N,ROTANG3/ROTANG2/10000. $ MULTIPLY BY 10000
PARAMR //C,N,FIX/ROTANG3/////V,N,ROTANGF $ FRACTION OF DEGREE
$
$ MODIFY TRAILER OF GPL TO INCLUDE SUPERELEMENT ID NUMBERS
$
MODTRL GPLS////SEID/PEID/GRIDINC1/GRIDINC2 $ INCLUDE SE IDS, GRIDINC
$
$ MODIFY TRAILER OF SIL TO INCLUDE SYMMETRY AND ROTATION DATA
$
MODTRL SILS////SYMNORML/ROTANGW/ROTANGF $ AXIS, ROTATION DATA
$
$ FORM PARTITION VECTOR IF REQUESTED
$
PARAML CASEDR//C,N,DTI/1/161//V,N,PARTNID $ GET PARTN ID

```

File 1. (cont.)

```

PARAM //C,N,LEV,N,NOPRTN/PARTNID/0 $ -1 IF PARTN ID .LE. 0
PURGE PRTNVEC,NOPRTN $ PURGE IF PARTN NOT USED
COND NOPRTN1,NOPRTN $ SKIP IF PARTN NOT USED
MATMOD EQEXINS,USEX,SILS,CASEDR,,/PRTNVEC,/
17/0/1/S,N,NOPRTN $ -1 IF NO PARTITION VEC
COND NOPRTN1,NOPRTN $ SKIP IF NO PART. VEC
MATGPR GPLS,USEX,SILS,PRTNVEC/H/G $ PRINT PART. VEC
PARAML PRTNVEC/TRAILER/2/V,N,NOROW $ NO. OF ROWS IN PRTNVEC
MATGEN ,PRTNNULL/7/NOROW/1 $ MACH. PREC. NULL MATRIX
ADD PRTNVEC,PRTNNULL/PRTNVEC1 $ MAKE PRTNVEC MACH. PREC.
LABEL NOPRTN1 $
$
$ WRITE DISPLACEMENTS IN BASIC COORDINATE SYSTEM
$
COND NOBASIC2,NOBASIC $ SKIP IF NO BASIC
VECPLOT UGVS,BGPDTS,EQEXINS,CSTMS,,/UGVBAS/0/0/1/UGVBAS $ BASIC CS
PARAML UGVBAS/TRAILER/1/V,N,NOCOL $ NO. OF COLUMNS IN UGVS
PARAML UGVBAS/TRAILER/2/V,N,NOROW $ NO. OF ROWS IN UGVS
MATGEN ,NULLMAT/7/NOROW/NOCOL $ MACH. PREC. NULL MATRIX
ADD NULLMAT,UGVBAS/UGVBASC $ MAKE UGVBAS MACH. PREC.
EQUIV UGVBASC,UGVBASIC/NOPRTN $ EQUIV IF NO PART. VEC.
COND NOPRTN2,NOPRTN $ SKIP IF NO PART. VEC.
PARTN UGVBASC,,PRTNVEC/UGVBASIC,,/1 $ ROW PARTITION
LABEL NOPRTN2 $
OUTPUT2 GPLS,SILS,BGPDTS,PRTNVEC1,UGVBASIC//0/UTBASIC $ BASIC CS MODES
LABEL NOBASIC2 $
$
$ WRITE DISPLACEMENTS IN DISPLACEMENT COORDINATE SYSTEMS
$
COND NODISPL2,NODISPL $ SKIP IF NO DISPL
EQUIV UGVS,UGVS1/NOPRTN $ EQUIV IF NO PART. VEC.
COND NOPRTN3,NOPRTN $ SKIP IF NO PART. VEC.
PARTN UGVS,,PRTNVEC/UGVS1,,/1 $ ROW PARTITION
LABEL NOPRTN3 $
DBFETCH /GPPTS,,,/MODEL/PEID $ FETCH GPPTS
OUTPUT2 GPLS,SILS,GPPTS,PRTNVEC1,UGVS1//0/UTDISPL $ DISP. CS MODES
LABEL NODISPL2 $
$
$ IF REQUESTED, SKIP THE REMAINDER OF THE DATA RECOVERY OPERATIONS
$
COND LBLNOP,DATAREC $ SKIP IF DATAREC .LE. -1
$
$--END OF SEMCOMB ALTER =====

```

FILE 2. Listing of IRSRED63.ALT

```
$ IRSRED - REDUCE MASS AND STIFFNESS MATRICES USING IRS METHOD
$ -----
$
$ THIS ALTER REDUCES THE STIFFNESS AND MASS MATRICES OF THE
$ RESIDUAL STRUCTURE USING THE "IMPROVED REDUCED SYSTEM" METHOD.
$ THIS METHOD IMPROVES UPON THE STANDARD GUYAN (STATIC)
$ REDUCTION BY INCLUDING THE EFFECTS OF MASS AT THE O-SET DOF.
$
$
$ REFERENCE:
$
$ O'CALLAHAN, J., "A PROCEDURE FOR AN IMPROVED REDUCED SYSTEM
$ (IRS) MODEL," 7TH INTERNATIONAL MODAL ANALYSIS CONFERENCE,
$ FEBRUARY, 1989.
$
$
$ REQUIREMENTS TO USE THIS ALTER -
$ -----
$ DATA BASES -
$ NO SPECIAL REQUIREMENTS
$ -----
$ EXECUTIVE DECK -
$ SOL 63
$ THIS ALTER
$ DIAG 8,20 RECOMMENDED
$ -----
$ CASE CONTROL DECK -
$ INCLUDE SEMG, SEKR, AND SEMR (OR SEALL) REQUESTS FOR THE
$ THE RESIDUAL STRUCTURE.
$
$ THIS ALTER SHOULD "NOT" BE INCLUDED WHEN PROCESSING UPSTREAM
$ COMPONENTS.
$ -----
$ BULK DATA DECK -
$
$ INCLUDE ASET OR OMIT CARDS TO SELECT THE A-SET DOF.
$
$ DO NOT INCLUDE Q-SET DOF FOR THE RESIDUAL STRUCTURE.
$ -----
$ EXAMPLE NASTRAN DECK-
$
$ ID TAM,IRSRED
$ SOL 63
$ TIME 30
$ DIAG 8,20
$
$ . THIS ALTER
$ .
$ CEND
$ TITLE = REDUCE RESIDUAL STRUCTURE USING IRS METHOD
$
$ SET 1000 = 0          $ RESIDUAL STRUCTURE
$ SEALL = 1000         $ ALL S.E. OPS FOR S.E. IN SET 1000
$
$
$ SUBCASE 1100
$ SUPER 100
$ LABEL = ANTENNA
$ METHOD = 50
$ SUBCASE 1200
```

File 2.

```

$ SUPER 200
$ LABEL = BUS STRUCTURE
$ METHOD = 50
$ SUBCASE 2000
$ LABEL = RESIDUAL STRUCTURE
$ METHOD = 25
$ $
$ BEGIN BULK
$ . TAM BULK DATA INCLUDING ASET CARDS
$ .
$ ENDDATA
$
$-----
$ HISTORY DOCUMENTATION -
$
$ VERSION 1.0 04-APR-89 CHRIS FLANIGAN
$ - ORIGINAL VERSION
$
$-----
$2345678901234567890123456789012345678901234567890123456789012
$ 1 2 3 4 5 6 7
$
$ DEFAULT VALUES FOR PARAMETERS
$
$ ALTER 1$ AFTER BEGIN
$ PARAM //C,N,NOP/V,Y,NOIRSRED=0$ 0 = USE IRS METHOD
$
$ STORE KFF FOR LATER USE
$
$ ALTER 381$ V65 AFTER LBL3
$ DBSTORE KFF//MODEL/SEID/DBSET1$ STORE KFF
$
$ CHANGE THE NAME OF GOAT AND KAA TO GOATS AND KAAS
$ (STATIC CONTRIBUTION)
$
$ ALTER 420,421$ V65 REPLACE FBS AND MPYAD
$ FBS LOO,UOO,KOA/GOATS/-1/-1/0/0$ FORM GOAT (STATIC)
$ MPYAD KAO,GOATS,KAA1/KAAS/////UNSYM$ KAA (STATIC)
$ ALTER 424,424$ V65 REPLACE DBSTORE
$ DBSTORE GOATS//MODEL/SEID/DBSET1$ STORE GOAT (STATIC)
$ ALTER 426,426$ V65 REPLACE EQUIV
$ EQUIV KAAS,KTT/NOQSET$ EQUIV IF NO Q-SET
$ ALTER 429,429$ V65 REPLACE UPARTN
$ UPARTN USET,KAAS/KQQ1,,,KTT/C,N,A/C,N,Q/C,N,T$ EXTRACT KQQ
$ ALTER 436,436$ V65 REPLACE DBSTORE
$ DBSTORE KAAS//MODEL/SEID/DBSET2$ STORE KAA (STATIC)
$
$ USE GOATS INSTEAD OF GOAT TO PERFORM THE STATIC
$ REDUCTION OF THE MASS MATRIX
$
$ ALTER 488,488$ V65 REPLACE DBSTORE
$ DBFETCH /GM,GOATS,DM,USET,/MODEL/PEID/DBSET3$ FETCH DATA
$ ALTER 490,490$ V65 REPLACE EQUIV
$ EQUIV GOATS,GOA/NP$ EQUIV
$ ALTER 511,511$ V65 REPLACE MPYAD
$ MPYAD MOO,GOATS,MOA/MOA1$ REDUCE O-SET MASS
$ ALTER 516,516$ V65 REPLACE EQUIV
$ EQUIV MTT,MAAS/NOQSET$ EQUIV IF NO Q-SET
$ ALTER 518,518$ V65 REPLACE UMERGE1
$ UMERGE1 USET,MTT,,,MAAS/C,N,A/C,N,T/C,N,Q/0$ SYMMETRIC MERGE
$ ALTER 521,522$ V65 REPLACE MPYAD

```

File 2. (cont.)


```

MPYAD MOA,GOATS,MAA1/MAA2/1 $ REDUCE O-SET MASS
MPYAD GOATS,MOA1,MAA2/MAAS/1////6 $ REDUCE O-SET MASS
ALTER 524,524 $ V65 REPLACE EQUIV
EQUIV MAAS,MTT/NOQSET $ EQUIV IF NO Q-SET
ALTER 527,527 $ V65 REPLACE UPARTN
UPARTN USET,MAAS/MTT,,,MQQ1/C,N,A/C,N,T/C,N,Q $ SYMMETRIC PARTN
ALTER 535,535 $ V65 REPLACE DBSTORE
DBSTORE MAAS/SOLID/SEID/DBSET2 $ STORE MAA (STATIC)
$
$ CALCULATE THE IMPROVED TRANSFORMATION MATRIX
$
$ GOAT = GOATS + GOATD
$
$ -1
$ GOATS = -KOO KOA
$
$ -1 -1
$ GOATD = KOO (MOO * GOATS + MOA) MAA KAA
$
$ NOTE: THE A-SET MASS MATRIX 'MUST' BE POSITIVE DEFINITE
$ SUCH THAT MAA CAN BE INVERTED. ALL ZERO MASS DOF
$ 'MUST' BE OMITTED.
$
DBFETCH /KFF,LOO,UOO,GOATS,KAAS/MODEL/PEID/DBSET3 $ FETCH SEKR DATA
SOLVE MAAS,KAAS/MINVK $ MAAS-INV * KAAS
MPYAD MOO,GOATS,MOA/MOA1 $ (MOO*GOATS) + MOA
MPYAD MOA1,MINVK/MOA2 $ MOA1 * (MAAS-INV*KAAS)
FBS LOO,UOO,MOA2/GOATD $ O-A TRANSFORM (DYNAMIC)
ADD GOATS,GOATD/GOAT $ TOTAL O-A TRANSFORM
DBSTORE GOAT/MODEL/SEID/DBSET1 $ STORE GOAT
$
$ FORM THE IMPROVED REDUCED STIFFNESS AND MASS MATRICES
$
MATGEN /IAA/1/NOASET $ A-SET IDENTITY MATRIX
VEC USET/VFOA/F/O/A $ F = O / A
MERGE GOAT,IAA,,,VFOA/TFA/1 $ ROW MERGE
SMPYAD TFA,KFF,TFA,,,/KAA/3////1////6 $ REDUCED K MATRIX
DBSTORE KAA/MODEL/SEID/DBSET2 $ STORE KAA
SMPYAD TFA,MFF,TFA,,,/MAA/3////1////6 $ REDUCED M MATRIX
DBSTORE MAA/SOLID/SEID/DBSET2 $ STORE MAA
$
$--END OF IRSRED-----

```

File 2. (cont.)

FILE 3. Listing of HRED63.ALT

```
$ HRED - FORM KAA AND MAA USING HYBRID REDUCTION
$ -----
$
$ THIS ALTER REDUCES THE STIFFNESS AND MASS MATRICES OF THE TEST-
$ ANALYSIS MODEL (TAM) RESIDUAL STRUCTURE TO THE A-SET DOF USING
$ "HYBRID REDUCTION". HYBRID REDUCTION IS BASED UPON CALCULATING
$ THE MODE SHAPES OF THE OMITTED (O-SET) DOF AS AN EXPANSION OF
$ THE PREVIOUSLY CALCULATED FINITE ELEMENT MODEL (FEM) MODE SHAPES.
$ HYBRID REDUCTION COMBINES THE EXACT REPRESENTATION OF THE MODAL
$ TAM AND APPROXIMATE REPRESENTATION OF THE RESIDUAL MODES FROM THE
$ STATIC TAM.
$
$ THE FEM MODES MUST BE PARTITIONED TO THE G-SET DOF OF THE TAM
$ RESIDUAL STRUCTURE AND WRITTEN TO AN OUTPUT4 FILE (SEE DMAP
$ "PARTNMOD"). THE FEM MODE SHAPES MUST HAVE THE SAME INTERNAL
$ SEQUENCE AS THE TAM. ALTERNATIVELY, THE FEM MODES FOR THE
$ TAM G-SET DOF MAY BE INPUT VIA AN OUTPUT2 FILE WITH THE
$ MODE SHAPES IN "MATPOOL" DMIG FORMAT. IF THE "MATPOOL" METHOD
$ IS USED, THE FEM MODES ARE AUTOMATICALLY PLACED INTO THE
$ INTERNAL SEQUENCE OF THE TAM.
$
$ NOTE THAT HYBRID REDUCTION IS APPLIED ONLY TO THE TAM RESIDUAL
$ STRUCTURE. STANDARD STATIC AND COMPONENT MODE REDUCTION IS
$ APPLIED TO UPSTREAM SUPERELEMENTS (IF ANY).
$
$
$ REFERENCES:
$
$ KAMMER, D.C., TBD (HYBRID TAM REDUCTION)
$
$ KAMMER, D.C., "TEST-ANALYSIS MODEL DEVELOPMENT USING AN EXACT
$ MODAL REDUCTION," INTERNATIONAL JOURNAL OF ANALYTICAL AND
$ EXPERIMENTAL MODAL ANALYSIS, OCTOBER, 1987, PP. 174-179.
$
$ LINK, M., "IDENTIFICATION OF PHYSICAL SYSTEM MATRICES USING
$ INCOMPLETE VIBRATION TEST DATA," 4TH INTERNATIONAL MODAL ANALYSIS
$ CONFERENCE, FEBRUARY, 1986.
$
$
$ REQUIREMENTS TO USE THIS ALTER -
$ -----
$ DATA BASES -
$ THE FOLLOWING DATA BASE FILES MUST BE AVAILABLE -
$ -TAM SYSTEM AND COMPONENT (IF ANY) DATA BASE(S)
$ -----
$ USER FILES -
$ THE FEM MODE SHAPES FOR THE TAM G-SET DOF MUST BE PRESENT ON
$ FORTRAN UNIT 11 OR THE UNIT DEFINED BY PARAM,UTUNIT (SEE "BULK
$ DATA DECK" BELOW). THE FEM MODES MAY BE IN OUTPUT4 OR
$ OUTPUT2/MATPOOL FORMAT (SEE PARAM,FEMFMT).
$ -----
$ EXECUTIVE DECK -
$ SOL 63
$ THIS ALTER
$ DIAG 8,20 RECOMMENDED
$ -----
$ CASE CONTROL DECK -
$ INCLUDE STANDARD REQUESTS FOR RUNNING THE RESIDUAL STRUCTURE
$ (SEMG, SEKR, AND SEMR) AND FOR RECOVERING RESULTS (DISPL = ALL,
$ OUTPUT(PLOT), ETC.).
```

File 3.

```

$-----
$ BULK DATA DECK -
$
$ OPTIONAL PARAMETERS -
$
$ PARAM,ENDCHECK - IF -1, END THE RUN AFTER CHECKING THE
$ TRANSFORMATION MATRIX
$ (DEFAULT = 0 - PERFORM ENTIRE SOLUTION)
$
$ PARAM,FEMUNIT - FORTRAN UNIT FOR THE FEM MODE SHAPE FILE
$ (DEFAULT = 11 - READ FEM MODES FROM UNIT 11)
$
$ PARAM,FEMFMT - FORMAT OF THE FEM MODE SHAPE FILE
$ -1 = OUTPUT2 MATPOOL FORMAT
$ 0 = OUTPUT4 BCD FORMAT
$ 1 = OUTPUT4 BINARY FORMAT
$ (DEFAULT = 0 - OUTPUT4 BCD FORMAT)
$-----
$ EXAMPLE NASTRAN DECK-
$
$ ID TAM,HRED
$ SOL 63
$ TIME 30
$ DIAG 8,20
$
$ . THIS ALTER
$ .
$ CEND
$ TITLE = FORM HYBRID TAM
$
$ SET 1000 = 0 $ RESIDUAL STRUCTURE
$ SEALL = 1000 $ ALL S.E. OPS FOR S.E. IN SET 1000
$
$ DISP = ALL $ RECOVER MODE SHAPES
$
$ SUBCASE 1100
$ SUPER = 100
$ LABEL = ANTENNA
$ METHOD = 100 $ COMPONENT MODES TO 100 HZ
$ SUBCASE 1200
$ SUPER = 200
$ LABEL = BUS STRUCTURE
$ METHOD = 100 $ COMPONENT MODES TO 100 HZ
$ SUBCASE 2000
$ LABEL = RESIDUAL STRUCTURE
$ METHOD = 50 $ SYSTEM MODES TO 50 HZ
$
$ BEGIN BULK
$
$ . STANDARD BULK DATA INCLUDING TAM ASET AND ASET1 CARDS
$
$ ENDDATA
$-----
$ HISTORY DOCUMENTATION -
$
$ VERSION 1.0 21-JUL-89 Daniel C. Kammer, Ph.D.
$ Dept. of Engineering Mechanics
$ University of Wisconsin
$ Madison, WI 53706
$ (608) 262-5724
$ - ORIGINAL VERSION
$ VERSION 2.0 23-SEP-89 CHRIS FLANIGAN

```

File 3. (cont.)

```

$ - RENAMED TO "HRED" (WAS "XHYBRID")
$ - USE SIMILAR DMAP SETUP "MRED"
$
=====
$2345678901234567890123456789012345678901234567890123456789012
$ 1 2 3 4 5 6 7
$
$ DEFAULT VALUES FOR PARAMETERS
$
ALTER 1$ AFTER BEGIN
PARAM //C,N,NOP/V,Y,ENDCHECK=0$ 0 = COMPLETE RUN
PARAM //C,N,NOP/V,Y,RESTART=0$ 0 = NON-RESTART RUN
PARAM //C,N,NOP/V,Y,FEMUNIT=11$ FEM MODE SHAPE FILE
PARAM //C,N,NOP/V,Y,FEMFMT=0$ 0 = FORMATTED (BCD)
$
$ SKIP THE REMAINDER OF SEKR FOLLOWING THE FORMATION OF THE
$ STATIC CONSTRAINT MODES GOAT (DO K MATRIX REDUCTION IN SEMR)
$
ALTER 420$ V65 AFTER FBS FOR GOAT
COND STATREDK,ACON$ SKIP IF NOT RESID STRUC
DBSTORE KFF,GOAT/MODEL/SEID/DBSET1$ STORE KFF AND GOAT
JUMP LBLMR$ SKIP REMAINDER OF SEKR
LABEL STATREDK$ REDUCE K - STATIC RED
$
$ FORM REQUIRED PARTITION VECTORS
$
ALTER 505$ V65 AFTER COND GNOMTT2
COND STATREDM,ACON$ SKIP IF NOT RESID STRUC
VEC USET/VGFX/G/F/COMP$ G = F / COMP
VEC USET/VFOA/F/O/A$ G = F / COMP
$
$ READ THE FEM MODE SHAPES FOR THE TAM G-SET DOF
$
COND HRESTRT,RESTART$ SKIP IF RESTART RUN
COND FEMOP2,FEMFMT$ SKIP IF FEMFMT .LE. -1
INPUTT4 /FEMPHIG,,,/1/FEMUNIT-/FEMFMT$ FEM MODES FROM OUTPUT4
PARAML FEMPHIG/TRAILER/2/V,N,NOFEMDOF$ NO. OF FEM DOF
PARAM //C,N,NE/V,N,BADFEM/NOFEMDOF/NOGSET$ -1 IF FEM NE TAM G-SET
COND LOOPER,BADFEM$ ERROR IF BAD FEM SIZE
JUMP DNRDFEM$ DONE READING FEM MODES
LABEL FEMOP2$ FEM MODES FROM OUTPUT2
INPUTT2 /MATPOOLF,,,/0/FEMUNIT$ READ NEXT DATA BLOCK
MTRXIN ,,MATPOOLF,EQEXINS,SILS,/FEMPHIG,/
V,N,NOGSET$ PROCESS DMIG DATA
LABEL DNRDFEM$ DONE READING FEM MODES
$
$ FORM TAM O-SET AND A-SET PARTITIONS OF FEM MODE SHAPES
$
PARTN FEMPHIG,VGFX/FEMPHIF,,,/1$ ROW PARTITION
PARTN FEMPHIF,VFOA/FEMPHIO,FEMPHIA,,,/1$ ROW PARTITION
DBSTORE FEMPHIG,FEMPHIO,FEMPHIA/MODEL/0/DBSET1$ STORE IN DATA BASE
$
$ T
$ CALCULATE = [FEMPHIA * FEMPHIA]
$
MPYAD FEMPHIA,FEMPHIA,PTP/1$ PHIA-T * PHIA
$
$ T
$ CALCULATE THE EIGENVALUES OF [FEMPHIA * FEMPHIA]
$ TO GET CONDITION NUMBER
$
PARAML PTP/TRAILER/1/V,N,NOMODES$ NUMBER OF MODES
MATGEN /HH/1/NOMODES$ H-SET IDENTITY MATRIX

```

File 3. (cont.)

```

MATMOD CASES,DYNAMICS,.../23/S,N,NP/S,N,LANCZOS $ EIG METHOD
COND PTP,EIG,LANCZOS $ JUMP IF LANCZOS METHOD
READ PTP,IHH,...DYNAMICS,CASES/PTPLAMA,PTPPHI,
PTPMI,PTPOEIGS/MODE/S,N,NOZSET $ SOLVE FOR PTP EIGENVALS
JUMP DNPTPEIG $ DONE WITH PTP EIG SOLVE
LABEL PTP,EIG $ START LANCZOS SOLVE
REIGL PTP,IHH,DYNAMICS,CASES/PTPLAMA,PTPPHI,
PTPMI,PTPMATS/V,I,READAPP/S,N,NOZSET $ SOLVE FOR PTP EIGENVALS
LABEL DNPTPEIG $ DONE WITH PTP EIG SOLVE
OFF PTP,EIGS,PTPLAMA/$ PRINT PTP EIGENVALUES
$
$ CALCULATE THE GENERALIZED INVERSE OF THE FEM A-SET MODES
$
$ T -1
$ GENERALIZED INVERSE = [FEMPHIA * FEMPHIA]
$
SETVAL /V,N,DCMPASYM/-1 $ DEFAULT DECOMP SYMMETRY
DECOMP PTP/PTPL,PTPU/S,N,DCMPASYM/S,N,MINDIAG/
S,N,DETSKALE/S,N,DETPOWERS/S,N,SING/
S,N,NNEGDIAG/S,N,MAXRAT $ DECOMPOSE PTP
PRTPARM /O/C,N,DCMPASYM $ SYMMETRY USED BY DECOMP
PRTPARM /O/C,N,MINDIAG $ MIN. DIAG TERM OF PTP
PRTPARM /O/C,N,DETSKALE $ SCALE FOR DETERMINANT
PRTPARM /O/C,N,DETPOWER $ POWER FOR DETERMINANT
PRTPARM /O/C,N,SING $ -1 IF PTP IS SINGULAR
PRTPARM /O/C,N,NNEGDIAG $ NO. NEG. TERMS ON DIAG
PRTPARM /O/C,N,MAXRAT $ MAX MATRIX/FACTOR RATIO
COND LOOPER,SING $ ERROR IF SINGULAR
FBS PTP,PTPL,IHH/PTPINV $ GENERALIZED INVERSE
DBSTORE PTP,PTPINV/MODEL/0/DBSET1 $ STORE IN DATA BASE
$
$ CHECK THE GENERALIZED INVERSE OF THE FEM A-SET MODES
$
MPYAD PTP,PTPINV,PTPINVCK $ SHOULD BE IDENTITY MTX
ADD PTPINVC,IHH/INVER/(-1.0,0.0) $ ERROR MATRIX
MATMOD INVER,.../INVERRMX,6 $ MAX ERROR IN EACH ROW
MATPRN INVERRMX,PTPINVCK/$ PRINT MAX ERR AND CHECK
$
$ IF REQUESTED, END THE RUN
$
COND FINIS,ENDCHECK $ END IF ENDCHECK .LT. 0
LABEL HRESTR $ RESTART FOR HYBRID RED
DBFETCH /FEMPHIO,FEMPHIA,PTP,PTPINV,/MODEL/0/DBSET1 $ FETCH FROM DB
$
$ CALCULATE THE MODAL REDUCTION TRANSFORMATION MATRIX
$
TRNSP FEMPHIA/FEMPHIAT $ TRANSPOSE
SMPYAD FEMPHIO,PTPINV,FEMPHIAT,.../DMREDOA/3 $ PHIO * PTP-INV * PHIA-T
DBSTORE DMREDOA/MODEL/0/DBSET1 $ STORE IN DATA BASE
$
$ REDUCE THE MASS MATRIX USING MODAL REDUCTION
$
MATGEN /IAA/1/V,N,NOASET $ A-SET IDENTITY MATRIX
MERGE DMREDOA,IAA,.../VFOA/TMREDF/1 $ ROW MERGE
SMPYAD TMREDF,MFF,TMREDF,.../MAAMR/3/1/1/6 $ MAAMR = T-T*MFF*T
$
$ GENERATE OBLIQUE PROJECTOR
$
SMPYAD FEMPHIA,FEMPHIA,MAAMR,.../UK/3/1/1 $ TRANSPOSE 2ND MATRIX
$
$ FORM STATIC TRANSFORMATION
$
MERGE GOAT,IAA,.../VFOATSREDF/1 $ ROW MERGE

```

File 3. (cont.)

```

$
$ GENERATE HYBRID TRANSFORMATION
$
ADD  TMREDFA,TSREDFA/DIFFMS/((-1.0,0.0))$  SUBTRACT TS FROM TM
MPYAD  DIFFMS,UK,TSREDFA/THREDFA/$  TH = TS + (TM-TS) * UK
PARTN  THREDFA,,VFOA/DHREDOA,,,1$  ROW PARTITION
DBSTORE DHREDOA/MODEL/0/DBSET1$  STORE HYBRID TRAN MAT
DBMGR  //7/MODEL/0/MODEL/0/DBSET1/DHREDOA/GOAT$ EQUIVALENT NAME
$
$ REDUCE THE STIFFNESS AND MASS MATRICES USING HYBRID REDUCTION
$
DBFETCH /KFF,,,/MODEL/0/DBSET1$  FETCH KFF
SMPYAD  THREDFA,KFF,THREDFA,,,/KAA/3////1////6$ KAA = T-T * KFF * T
SMPYAD  THREDFA,MFF,THREDFA,,,/MAA/3////1////6$ MAA = T-T * MFF * T
DIAGONAL KAA/KAADIAG$  EXTRACT DIAGONAL TERMS
DIAGONAL MAA/MAADIAG$  EXTRACT DIAGONAL TERMS
MATGPR  GPLS,USET,SILS,MAADIAG//H/A$  PRINT DIAGONAL TERMS
MATGPR  GPLS,USET,SILS,KAADIAG//H/A$  PRINT DIAGONAL TERMS
DBSTORE KAA/MODEL/0/DBSET2$  STORE KAA
DBMGR  //10/MODEL/0/DBSET2///SEKRDONE$  SEKR DONE
JUMP  GNOMTT2$  DONE WITH M MODAL RED
LABEL  STATREDM$  BEGIN M STATIC RED
$
$ CALCULATE ORTHOGONALITY AND CROSS-ORTHOGONALITY MATRICES
$
ALTER  818$ V65  AFTER FORMING PHIA
DBFETCH /FEMPHIA,,,/MODEL/0/DBSET1$  FETCH FROM DATA BASE
SMPYAD  FEMPHIA,MAA,FEMPHIA,,,/ORTHO/3////1$ ORTHO USES ONLY FEM
SMPYAD  FEMPHIA,MAA,PHIA,,,/XORTHO/3////1$ XORTHO USES FEM AND TAM
MATPRT  ORTHO// $  PRINT ORTHO MATRIX
MATPRT  XORTHO// $  PRINT XORTHO MATRIX
$

```

FILE 4. Listing of WTTAM.DMP

```

BEGIN $ WRITE TAM DATA AND OUTPUT4 FILE          (WTTAM)
$-----
$
$ THIS DMAP SEQUENCE WRITES THE TAM DATA TO TWO OUTPUT4 FILES.
$ SELECTED DATA MAY ALSO BE PRINTED IN THE NASTRAN OUTPUT FILE
$ TO DOCUMENT THE TAM RESULTS.
$
$ THE A-SET MASS AND STIFFNESS MATRICES ARE WRITTEN TO THE
$ FIRST OUTPUT4 FILE. THE MODAL FREQUENCIES (HZ), MODE SHAPES,
$ AND GENERALIZED MASS ARE WRITTEN TO THE SECOND OUTPUT4 FILE.
$ OPTIONALLY, THE 6X6 RIGID BODY MASS MATRIX AND "UNIT" RIGID
$ BODY MODE SHAPES CAN BE WRITTEN FOR MODAL EFFECTIVE MASS
$ CALCULATIONS (SEE PARAM,EFFMAS).
$
$ IF REQUESTED BY PARAM EXTSORT, THE MASS, STIFFNESS, MODE SHAPE,
$ AND UNIT RIGID BODY MODE MATRICES WILL BE CONVERTED FROM INTERNAL
$ TO EXTERNAL (NUMERICALLY ASCENDING) SORT. THE MATRIX NAMES
$ WRITTEN TO THE OUTPUT4 FILES WILL CHANGE AS SHOWN BELOW:
$
$   MAA -> MAAEXT   PHIA -> PHIAEXT
$   KAA -> KAAEXT   URBA -> URBAEXT
$
$ THE INTERNAL-TO-EXTERNAL SORT CONVERSION IS ONLY NEEDED IF THE
$ TAM RESIDUAL STRUCTURE IS INTERNALLY RESEQUENCED (NOT IN NUMERICALLY
$ ASCENDING ORDER) AND THE TAM MATRICES ARE REQUIRED TO BE IN EXTERNAL
$ SORT. THE INTERNAL-TO-EXTERNAL SORT CONVERSION IS USUALLY NOT
$ NEEDED FOR TAMS CREATED USING ONE OR MORE UPSTREAM SUPERELEMENTS.
$ IT WILL PROBABLY BE NEEDED WHEN THE TAM IS CREATED WITHOUT
$ SUPERELEMENTS.
$
$
$ THE MATRICES WRITTEN ARE AS FOLLOWS:
$
$   NAME      DESCRIPTION      NROW NCOL UNIT OPTIONAL?
$   -----
$   MAA(EXT) REDUCED MASS MATRIX      A-SET A-SET 11  NO
$   KAA(EXT) REDUCED STIFFNESS MATRIX  A-SET A-SET 11  NO
$   RBMO      RIGID BODY MASS MATRIX   6  6  11  YES
$
$   PHIA(EXT) MODE SHAPES              A-SET NMODE 12  NO
$   FREQHZ    MODAL FREQUENCIES (HZ)   NMODE  1  12  NO
$   GENMASS   GENERALIZED MASS (DIAG ONLY) NMODE  1  12  NO
$   URBA(EXT) "UNIT" RIGID BODY MODE SHAPES A-SET  6  12  YES
$
$
$ THE FOLLOWING INFORMATION IS WRITTEN TO THE NASTRAN OUTPUT FILE:
$
$   DESCRIPTION      OPTIONAL? PARAM
$   -----
$   GEOMETRY DATA FOR RESIDUAL STRUCTURE GRIDS  YES  GEOMPRT
$   SET ALLOCATION TABLES (USET TABLES)        YES  USETPRT
$   DIAGONAL TERMS OF THE REDUCED STIFFNESS MATRIX  NO
$   DIAGONAL TERMS OF THE REDUCED MASS MATRIX      NO
$   REAL EIGENVALUE SUMMARY                      NO
$   MODE SHAPES OF THE A-SET DOF                  YES  (CASE CON)
$   RIGID BODY MASS MATRIX                        YES  EFFMASS
$   UNIT RIGID BODY MODE SHAPES                  YES  EFFMASS
$
$
$ REQUIREMENTS TO USE THIS DMAP SEQUENCE -

```

```

$-----
$ DATA BASES -
$ THE FOLLOWING DATA BASE FILES MUST BE AVAILABLE -
$   -TAM DATA BASE
$-----
$ USER FILES -
$ THE TAM DATA WILL BE WRITTEN TO FORTRAN UNITS 11 AND 12 IN
$ OUTPUT4 FORMAT. ALSO SEE PARAM,OP4FMT IN THE BULK DATA DECK.
$-----
$ EXECUTIVE DECK -
$ INCLUDE THIS DMAP SEQUENCE (DO NOT USE A RIGID FORMAT)
$ DIAG 8,14,20 RECOMMENDED
$-----
$ CASE CONTROL DECK -
$ A-SET MODE SHAPES MAY BE PRINTED BY AN "SVECTOR=ALL" REQUEST.
$-----
$ BULK DATA DECK -
$
$ OPTIONAL PARAMETERS -
$
$ PARAM,EFFMASS - FORM RB MASS MATRIX AND UNIT RB MODES IF .GE. 0
$   (DEFAULT = -1 - DO NOT FORM EFFECTIVE MASS DATA)
$
$ PARAM,GEOMPRT - PRINT GEOMETRY DATA IF .GE. 0
$   (DEFAULT = -1 - DO NOT PRINT GEOMETRY DATA)
$
$ PARAM,GRDPNTEM - ID OF THE REFERENCE GRID FOR THE EFFECTIVE
$   MASS OF THE RIGID BODY ROTATION MODES
$   (DEFAULT = 0 - ORIGIN OF BASIC COORD. SYSTEM)
$
$ PARAM,OP4FMT - WRITE OUTPUT4 FILE IN BINARY (1) OR BCD
$   (.NE. 1) FORMAT.
$   (DEFAULT = 0 - WRITE BCD FORMAT)
$
$ PARAM,USETPRT - PRINT USET TABLE BY SET (0), DOF (1), OR BOTH
$   (2). DO NOT PRINT IF -1.
$   (DEFAULT = 0 - PRINT USET TABLE BY SET)
$
$ PARAM,WTMASS - PRINT THE MASS DATA IN WEIGHT UNITS
$   (DEFAULT = 1.0 - NO CONVERSION FOR WEIGHT UNITS)
$-----
$ EXAMPLE NASTRAN DECK-
$
$ ID PRETEST,TAM
$ TIME 10
$ DIAG 8,14,20
$
$ . THIS DMAP SEQUENCE
$ .
$ CEND
$ TITLE = WRITE TAM DATA FOR PRETEST MODEL
$
$ SVECTOR = ALL $ PRINT A-SET MODE SHAPES
$
$ BEGIN BULK
$
$ $ PRINT GEOMETRY DATA
$ PARAM,GEOMPRT,0
$
$ $ PRINT USET TABLE
$ PARAM,USETPRT,0
$
$ $

```

File 4. (cont.)


```

$ $ PRINT MASS DATA IN WEIGHT UNITS
$ PARAM,WTMASS,.00259
$ $
$ $ CALCULATE EFFECTIVE MASS AND WRITE MATRICES TO OUTPUT4 FILES
$ $ REFERENCE POINT FOR EFFECTIVE MASS IS GRID 101
$ PARAM,EFFMASS,0
$ PARAM,GRDPNTEM,101
$ $
$ ENDDATA
$
$-----
$ HISTORY DOCUMENTATION -
$
$ VERSION 1.0 22-SEP-88 CHRIS FLANIGAN
$ - ORIGINAL VERSION
$ VERSION 2.0 04-DEC-88 CHRIS FLANIGAN
$ - WRITE MAA AND KAA TO UNIT 11, FREQHZ AND PHIA TO UNIT 12
$ VERSION 2.1 06-JAN-89 CHRIS FLANIGAN
$ - WRITE FREQHZ MATRIX AFTER PHIA MATRIX
$ VERSION 3.0 18-JAN-89 CHRIS FLANIGAN
$ - ADD MODAL EFFECTIVE MASS CALCULATIONS
$ VERSION 4.0 26-JAN-89 CHRIS FLANIGAN
$ - ADD EXTERNAL SORT OPTION
$ VERSION 4.1 02-MAR-89 CHRIS FLANIGAN
$ - REPLACE SMPYAD WITH MPYAD
$ - PRINT A-SET UNIT RIGID BODY MODES (URBA)
$
$-----
$23456789012345678901234567890123456789012345678901234567890123456789012
$ 1 2 3 4 5 6 7
$
$ SET DEFAULT VALUES
$
PARAM //C,N,NOP/V,Y,EFFMASS=-1 $ EFFECTIVE MASS OPTION
PARAM //C,N,NOP/V,Y,EXTSORT=-1 $ EXTERNAL SORT OPTION
PARAM //C,N,NOP/V,Y,GEOMPRT=-1 $ GEOMETRY PRINT OPTION
PARAM //C,N,NOP/V,Y,GRDPNTEM=0 $ REF. GRID FOR RB MODES
PARAM //C,N,NOP/V,Y,OP4FMT=0 $ OUTPUT4 FORMAT
PARAM //C,N,NOP/V,Y,USETPRT=0 $ USET TABLE PRINT OPTION
$
$ FETCH THE GEOMETRY DATA
$
DBFETCH /GPLS,SILS,EQEXINS,USET,/0/0 $ GEOMETRY DATA
DBFETCH /CSTMS,GPDTS,BGPDTS,/0/0 $ GEOMETRY DATA
PARAML USET//USET/////C,N,A/V,N,NOASET/
C,N,G/V,N,NOGSET $ NO. OF DOF IN SETS
VEC USET/VGAX/G/A/COMP $ G = A / COMP
$
$ PRINT THE GEOMETRY DATA
$
COND DNGEOM,GEOMPRT $ SKIP IF GEOMPRT .LT. 0
TABPRT CSTMS/CSTM $ COORDINATE SYSTEMS
TABPRT GPLS/GPL $ GRID POINT LIST
TABPRT GPDTS/GPDT $ GRID POINT DEF. TABLE
TABPRT BGPDTS/BGPD $ BASIC GRID POINT DEF.
LABEL DNGEOM $ DONE WITH GEOMETRY
$
$ IF REQUESTED, PRINT THE USET TABLES
$
COND DNUSET,USETPRT $ SKIP IF USETPRT .LT. 0
TABPRT USET,EQEXINS//USET/V,Y,USETPRT/V,Y,USETSEL $ PRINT USET TABLE
LABEL DNUSET $ DONE WITH USET TABLE
$

```

File 4. (cont.)

```

$ FETCH A-SET MASS AND STIFFNESS MATRICES
$
DBFETCH /MAA,KAA,,,/0/0 $          A-SET M AND K MATRICES
PARAML MAA/PRESENCE////V,N,BADMAA $ -1 IF NO MAA
PARAML KAA/PRESENCE////V,N,BADKAA $ -1 IF NO KAA
COND ERROR,BADMAA $          ERROR IF NO MAA
COND ERROR,BADKAA $          ERROR IF NO KAA
$
$ PRINT DIAGONAL TERMS OF A-SET MASS AND STIFFNESS MATRICES.
$ USE PARAM,WTMASS TO PRINT MASS TERMS IN WEIGHT UNITS.
$
DIAGONAL MAA/MAADIAG1 $          STRIP DIAGONAL TERMS
PARAMR //C,N,DIV/V,N,MW/1.0/C,Y,WTMASS=1.0 $ MW = 1 / WTMASS
PARAMR //C,N,COMPLEX//V,N,MW/0.0/V,N,MASSWT $ MASSWT
ADD MAADIAG1/MAADIAG/MASSWT $      MASS-TO-WEIGHT
MATGPR GPLS,USE,SILS,MAADIAG/H/A $ PRINT M DIAG TERMS
DIAGONAL KAA/KAADIAG $          STRIP DIAGONAL TERMS
MATGPR GPLS,USE,SILS,KAADIAG/H/A $ PRINT K DIAG TERMS
$
$ FETCH THE MODAL RESULTS
$
DBFETCH /LAMA,PHIA,,,/0/0 $          MODAL RESULTS
PARAML LAMA/PRESENCE////V,N,BADLAMA $ -1 IF NO LAMA
PARAML PHIA/PRESENCE////V,N,BADPHIA $ -1 IF NO PHIA
COND ERROR,BADLAMA $          ERROR IF NO LAMA
COND ERROR,BADPHIA $          ERROR IF NO PHIA
$
$ PRINT THE EIGENVALUE SUMMARY
$
OFF LAMA/$          PRINT EIGEN. SUMMARY
$
$ FORM THE FREQUENCY (HZ) AND GENERALIZED MASS MATRICES
$
LAMX „LAMA/LAMAMAT/1 $          MAKE MATRIX FROM LAMA
MATMOD LAMAMAT,,,,/FREQHZ/1/3 $ COL 3 = FREQ. (HZ)
MATMOD LAMAMAT,,,,/GENMASS/1/4 $ COL 4 = GEN. MASS
$
$ IF REQUESTED, PRINT THE MODE SHAPES
$
VDR CASECC,EQEXINS,USE,PHIA,LAMA,,/OPHIA,/REIG/
DIRECT/0/S,N,NOOPHIA/S,N,NOPREQ/1 $ PROCESS SDISP REQUEST
COND DNPHIA,NOOPHIA $          SKIP IF NO SDISP REQ
OFF OPHIA/S,N,CARDNO $          PRINT A-SET MODES
LABEL DNPHIA $          DONE WITH A-SET MODES
$
$ WRITE THE TAM MASS, STIFFNESS, AND MODE SHAPE MATRICES
$ IN INTERNAL OR EXTERNAL SORT
$
COND INTERN1,EXTSORT $          SKIP IF EXTSORT .I.E. -1
MATGEN EQEXINS/INTXT/9/0/NOGSET $ INTERNAL-TO-EXTERNAL
MERGE MAA,,,VGAX,/MAAG/ $          SYM. MERGE TO G-SET
MERGE KAA,,,VGAX,/KAAG/ $          SYM. MERGE TO G-SET
MERGE PHIA,,,VGAX/PHIAG/1 $          ROW MERGE TO G-SET
MPYAD INTXT,MAAG,/MAAGEXT1/1 $      TRANSPOSE FIRST TERM
MPYAD MAAGEXT1,INTXT,/MAAGEXT1/1 $  EXTERNAL SORT
MPYAD INTXT,KAAG,/KAAGEXT1/1 $      TRANSPOSE FIRST TERM
MPYAD KAAGEXT1,INTXT,/KAAGEXT1/1 $  EXTERNAL SORT
MPYAD INTXT,PHIAG,/PHIAGEXT1/1 $    EXTERNAL SORT
MPYAD INTXT,VGAX,/VGAXEXT1/1 $      EXTERNAL SORT
PARTN MAAGEXT,VGAXEXT,/MAAEXT,,,/ $ SYM. PARTN TO A-SET
PARTN KAAGEXT,VGAXEXT,/KAAEXT,,,/ $ SYM. PARTN TO A-SET
PARTN PHIAGEXT,VGAXEXT,/PHIAEXT,,,/1 $ ROW PARTN TO A-SET
OUTPUT4 MAAEXT,KAAEXT//1/11/OP4FMT $ TAM MASS AND STIFFNESS

```

File 4. (cont.)

```

OUTPUT4 PHIAEXT//1/12/OP4FMT $      TAM MODE SHAPES
JUMP DNINEX1 $      JUMP TO LABEL DNINEX1
$
LABEL INTERN1 $      INTERNAL SORT
OUTPUT4 MAA,KAA//1/11/OP4FMT $      TAM MASS AND STIFFNESS
OUTPUT4 PHIA//1/12/OP4FMT $      TAM MODE SHAPES
LABEL DNINEX1 $      DONE WITH INT-EXT SORT
$
$ WRITE THE TAM FREQUENCIES (HZ) AND GENERALIZED MASS
$
OUTPUT4 FREQHZ,GENMASS//0/12/OP4FMT $      TAM FREQ AND GEN. MASS
$
$ CHECK IF EFFECTIVE MASS IS TO BE CALCULATED
$
COND FINIS,EFFMASS $      SKIP IF EFFMASS .LE. -1
$
$ GENERATE RIGID BODY VECTORS USING GEOMETRY
$
VECPLOT ,,BGPPTS,EQEXINS,CSTMS,,URBGT/GRDPNTEM/0/4 $ UNIT RB VECTORS
TRNSP URBGT/URBG $      TRANSPOSE
PARTN URBG,,VGAX/URBA,,/1 $      ROW PARTN TO A-SET
MATGPR GPLS,USET,SILS,URBA/H/A $      PRINT UNIT RB MODES
$
$ NORMALIZE MODE SHAPES TO UNIT GENERALIZED MASS
$
MATMOD GENMASS,,,,/GENM,/28 $      FORM SQ. SYM. MATRIX
SOLVE GENM,/GENMINV $      INVERT
DIAGONAL GENMINV/PHISCALE/SQUARE/5 $      TAKE SQUARE ROOT
MPYAD PHIA,PHISCALE,/PHIANRM $      SCALE MODES
$
$ GENERATE RIGID MASS MATRIX
$
MPYAD URBA,MAA,/RBMO1/1 $      TRANSPOSE FIRST TERM
MPYAD RBMO1,URBA,/RBMO/////6 $      6X6 RB MASS MATRIX
DBSTORE URBA,RBMO//0/0 $      STORE IN DATABASE
MATPRT RBMO// $      PRINT RIGID BODY MASS
DIAGONAL RBMO/RBMODINV/SQUARE/-1. $      INVERT DIAG TERMS
$
$ COMPUTE EFFECTIVE MASS
$
SMPYAD PHIANRM,MAA,URBA,,/MAR/3////1 $      PHI-T * M * URB
DIAGONAL MAR/MARSQ/WHOLE/2. $      MAR SQUARED
MPYAD MARSQ,RBMODINV,EFFMAST $      NORM-MODAL EFF MASS DIST
PARAML PHIA/TRAILER/1/V,N,NOMODES $      NUMBER OF MODES
MATGEN ,/IH/6/NOMODES/0/NOMODES $      H-SIZE UNITY COLUMN
MPYAD IH,EFFMAST,TEFFMAST/1/ $      SUM OVER MODES (ROWS)
TRNSP EFFMAST/EFFMASS $      TRANSPOSE
TRNSP TEFFMAST/TEFFMASS $      TRANSPOSE
$
$ PRINT EFFECTIVE MASS
$
MATPRT EFFMASS// $      PRINT EFFECTIVE MASS
MATPRT TEFFMASS// $      PRINT TOTAL EFF MASS
DBSTORE EFFMASS,TEFFMASS//0/0 $      STORE IN DATA BASE
$
$ WRITE THE 6X6 RIGID BODY MASS MATRIX
$
OUTPUT4 RBMO//0/11/OP4FMT $      RB MASS MATRIX
$
$ WRITE THE UNIT RIGID BODY MODES IN INTERNAL OR EXTERNAL SORT
$
COND INTERN2,EXTSORT $      SKIP IF EXTSORT .LE. -1
MERGE URBA,,,,VGAX/URBAG/1 $      ROW MERGE TO G-SET

```

File 4. (cont.)

```

MPYAD INTEXT,URBAG,URBAGEXT/1 $      EXTERNAL SORT
PARTN  URBAGEXT,,VGAXEXT/URBAEXT,,,/1 $  ROW PARTN TO A-SET
OUTPUT4 URBAEXT//0/12/OP4FMT $      UNIT RIGID BODY MODES
JUMP  DNINEX2 $      JUMP TO LABEL DNINEX2
$
LABEL  INTERN2 $      INTERNAL SORT
OUTPUT4 URBA//0/12/OP4FMT $      UNIT RIGID BODY MODES
LABEL  DNINEX2 $      DONE WITH INT-EXT SORT
$
JUMP  FINIS $      DONE
$
$ ERROR
$
LABEL  ERROR $
PRTPARM //0//1 $      PRINT PARAMETER TABLE
$
$ END
$
LABEL  FINIS $
DBMGR  //2////1 $      PRINT DB DICTIONARY
END $

```

FILE 5. Listing of PARTNMODX.DMP

```
BEGIN $ PARTITION MODE SHAPES TO A-SET DOF          (PARTNMOD)
$
$ THIS DMAP SEQUENCE PARTITIONS THE MODE SHAPES TO THE A-SET OF
$ THE DOF DEFINED IN THE BULK DATA DECK. THE ORIGINAL MODES ARE
$ READ FROM AN OUTPUT4 FILE (BCD FORMAT). THE NUMBER OF DOF
$ DEFINED BY GRID AND/OR SPOINT CARDS IN THE BULK DATA DECK MUST
$ EXACTLY MATCH THE NUMBER OF ROWS IN THE MODE SHAPE MATRIX.
$ THE MODE SHAPES ARE PARTITIONED TO THE A-SET DOF AS DEFINED
$ BY ASET/ASET1/OMIT/OMIT1 CARDS IN THE BULK DATA DECK. IN
$ ADDITION, RIGID BODY MODES CAN ALSO BE ELIMINATED FROM THE
$ A-SET MODE SHAPES (SEE PARAM,ELASTIC AND PARAM,NRBMODE).
$
$ THE A-SET MODES ARE WRITTEN TO AN OUTPUT4 FILE (BCD FORMAT). IF
$ REQUESTED, THE A-SET MODES WILL ALSO BE WRITTEN IN DMIG FORMAT
$ (SEE PARAM,WDMIG AND PARAM,PUNDMIG).
$
$
$ SPECIAL INSTRUCTIONS TO USE THIS DMAP SEQUENCE:
$-----
$
$ USER FILES:
$
$ THE ORIGINAL (G-SET) MODE SHAPES ARE READ FROM AN OUTPUT4
$ FILE IN BCD FORMAT (PARAM,UTUNIT1 - DEFAULT = 11).
$
$ THE PARTITIONED (A-SET) MODE SHAPES ARE WRITTEN TO AN OUTPUT4
$ FILE IN BCD FORMAT (PARAM,UTUNIT2 - DEFAULT = 12).
$
$ THE PARTITIONED (A-SET) MODE SHAPES ARE WRITTEN TO AN OUTPUT2
$ FILE IN DMIG FORMAT (PARAM,UTUNIT3 - DEFAULT = 13)
$
$-----
$
$ DATA BASE FILES:
$
$ NONE
$
$-----
$
$ EXECUTIVE CONTROL DECK:
$
$ INCLUDE THIS DMAP SEQUENCE. DO NOT USE A RIGID FORMAT.
$
$-----
$
$ CASE CONTROL DECK:
$
$ NO SPECIAL INPUT IS REQUIRED.
$
$-----
$
$ BULK DATA DECK:
$
$ GRID AND/OR SPOINT CARDS MUST BE PROVIDED FOR THE ROWS IN
$ THE MODE SHAPE MATRIX. IF THE ROW ID NUMBERS ARE NOT IN
$ NUMERICALLY ASCENDING ORDER, SEQGP CARDS MUST BE DEFINED TO
$ CORRECTLY SEQUENCE THE GRIDS/SPOINTS WITH THE CORRESPONDING
$ ROWS.
$
$ ASET/ASET1/OMIT/OMIT1 CARDS MUST BE DEFINED TO SELECT THE
```

```

$ A-SET DOF.
$
$ OPTIONAL PARAMETERS:
$
$ PARAM,ELASTIC - OPTION TO PARTITION TO THE ELASTIC MODES
$ (DEFAULT = -1 : KEEP ALL MODES)
$
$ PARAM,NRBMODE - NUMBER OF RIGID BODY MODES FOR "PARAM,ELASTIC"
$ (DEFAULT = 6)
$
$ PARAM,WTDmig - IF .GE. 0, WRITE A-SET MODES IN DMIG FORMAT TO
$ OUTPUT2 FILE
$ (DEFAULT = -1 : DO NOT WRITE DMIG DATA)
$
$ PARAM,PUNDMIG - IF WTDmig .GE. 0 AND PUNDMIG .NE. 0, PUNCH A-SET
$ MODES IN DMIG BULK DATA CARD FORMAT
$ (DEFAULT = 0 : DO NOT PUNCH DMIG CARDS)
$
$ PARAM,PUNCC - CONTINUATION MNEMONIC USED BY PUNCHED DMIG CARDS
$ (DEFAULT = BLANK : USE AUTO-CONTINUATION OPTION)
$
$ PARAM,OP4FMT - WRITE OUTPUT4 FILE IN BINARY (1) OR BCD
$ (.NE. 1) FORMAT.
$ (DEFAULT = 0 - WRITE BCD FORMAT)
$
$ PARAM,IP4FMT - READ INPUT4 FILE IN BINARY (1) OR BCD
$ (.NE. 1) FORMAT.
$ (DEFAULT = 0 - READ BCD FORMAT)
$
$ PARAM,UTUNIT1 - ORIGINAL (INPUT) MODE SHAPES (OUTPUT4 BCD)
$ (DEFAULT = 11)
$
$ PARAM,UTUNIT2 - PARTITIONED (OUTPUT) MODE SHAPES (OUTPUT4 BCD)
$ (DEFAULT = 12)
$
$ PARAM,UTUNIT3 - PARTITIONED (OUTPUT) MODE SHAPES (OUTPUT2 DMIG)
$ (DEFAULT = 13)
$
$-----
$ HISTORY:
$
$ 20-OCT-86 DAN KAMMER
$ -ORIGINAL VERSION
$ 15-JUN-88 CHRIS FLANIGAN
$ -ADD CHECK FOR PROPER NUMBER OF G-SET DOF
$ -ADD PARAM,NRBMODE FOR ELASTIC MODE PARTITION
$ -REWRITE THE ELASTIC MODE PARTITION OPERATIONS FOR EFFICIENCY
$ -ENHANCE DOCUMENTATION
$ 08-JAN-89 CHRIS FLANIGAN
$ -ADD DMIG OPTION
$ 07-MAR-89 CHRIS FLANIGAN
$ -READ FREQHZ AND GENMDIAG MATRICES FROM FEM MODES FILE
$ -ADD PARAM USETPRT AND USETSEL
$ 14-JUN-90 ANDY FREED
$ -REMOVE DATABASE USAGE
$ -ADD PARAM IP4FMT AND OP4FMT
$
$-----
$2345678901234567890123456789012345678901234567890123456789012
$ 1 2 3 4 5 6 7
$
$ DEFAULT VALUES

```

File 5. (cont.)

II-XX

```

$
PARAM //C,N,NOP/V,Y,ELASTIC=-1 $      ELASTIC PARTN OPTION
PARAM //C,N,NOP/V,Y,IP4FMT=0 $        INPUT4 FORMAT
PARAM //C,N,NOP/V,Y,MODEL=0 $          MODEL ID
PARAM //C,N,NOP/V,Y,NRBMODE=6 $        NO. OF RB MODES
PARAM //C,N,NOP/V,Y,OP4FMT=0 $          OUTPUT4 FORMAT
PARAM //C,N,NOP/V,Y,PUNDMIG=0 $         PUNCH DMIG OPTION
PARAM //C,N,NOP/V,Y,CFID=0 $            SUPERELEMENT ID
PARAM //C,N,NOP/V,Y,USE1PRT=0 $         USE1 TABLE PRINT
PARAM //C,N,NOP/V,Y,UTUNIT1=11 $        INPUT MODE SHAPES
PARAM //C,N,NOP/V,Y,UTUNIT2=12 $        OUTPUT4 MODE SHAPES
PARAM //C,N,NOP/V,Y,UTUNIT3=13 $        OUTPUT2 MODE SHAPES
PARAM //C,N,NOP/V,Y,WTDmig=-1 $         WRITE DMIG OPTION
$
$ PROCESS THE BULK DATA INFORMATION
$
GP1  GEOM1,GEOM2,/GPLS,EQEXINS,GPDTS,CSTMS,BGPDTS,
      SILS/S,N,NOGSET/0/0 $             PROCESS GEOMETRY DATA
$
$ GENERATE USET TABLE
$
GP4  CASECC,GEOM4,EQEXINS,SILS,GPDTS,BGPDTS,CSTMS/
      RG,YS,USET,/NOGSET/S,N,NOMSET/S,N,NOSSET/
      S,N,NOOSET/S,N,NORSET/0/0/0/0 $   PROCESS SET INFORMATION
COND DNUSTPRT,USETPRT $                 SKIP IF USETPRT .LE. -1
TABPRT USET,EQEXINS//USET/V,Y,USETPRT/V,Y,USETSEL $ PRINT USET TABLE
LABEL DNUSTPRT $                       DONE WITH USET PRINT
$
$ READ G-SET MODE SHAPES FROM AN OUTPUT4 FILE
$
INPUT4 /PHIG,FREQHZ,GENM,,/3/V,Y,UTUNIT1/-1/OP4FMT $ READ MODAL DATA
PARAML PHIG//TRAILER/2/V,N,NROWPHIG $   NO. OF ROWS IN PHIG
PARAM //C,N,NE/V,N,BADGSET/NOGSET/NROWPHIG $ -1 IF G-SET .NE. ROWS
COND ERROR,BADGSET $                   ERROR IF BAD G-SET
$
$ PARTITION TO ELASTIC MODES ONLY
$
EQUIV PHIG,PHIGEL/ELASTIC $             EQUIV IF ELASTIC = -1
EQUIV FREQHZ,FREQHZEL/ELASTIC $         EQUIV IF ELASTIC = -1
EQUIV GENM,GENMEL/ELASTIC $             EQUIV IF ELASTIC = -1
COND DNELAS1,ELASTIC $                  SKIP IF ELASTIC = -1
PARAML PHIG//TRAILER/1/V,N,NMODE $       NUMBER OF MODES
MATGEN /VHRBEL/6/NMODE/NRBMODE/NMODE $   H = RB / ELASTIC
MATPRN VHRBEL// $                       PRINT PARTITION VECTOR
PARTN PHIG,VHRBEL,,PHIGEL,/1 $          COLUMN PARTN TO ELASTIC
PARTN FREQHZ,,VHRBEL,FREQHZEL,/1 $      ROW PARTN TO ELASTIC
PARTN GENM,,VHRBEL,GENMEL,/1 $          ROW PARTN TO ELASTIC
LABEL DNELAS1 $                         DONE WITH ELASTIC PARTN
$
$ PARTITION MODE SHAPES TO A-SET DOF
$
VEC USET/VGAX/G/A/COMP $                G = A / COMP
PARTN PHIGEL,,VGAX/PHIA,,,/1 $          ROW PARTITION TO A-SET
$
$ WRITE A-SET MODES TO AN OUTPUT4 FILE
$
OUTPUT4 PHIA,FREQHZEL,GENMEL/-1/UTUNIT2/OP4FMT $ WRITE MODAL DATA
$
$ IF REQUESTED, WRITE THE A-SET MODES TO AN OUTPUT2
$ FILE IN DMIG FORMAT
$
COND FINIS,WTDmig $                     SKIP IF WTDmig .LT. 0
MERGE PHIA,,,,VGAX/PHIAG/1 $            ROW MERGE TO G-SET

```

File 5. (cont.)

```

MATGEN EQEXINS/INTEXT/9/0/NOGSET $      INT-TO-EXT TRANSFORM
MPYAD  INTEXT,PHIAG/PHIAGEXT/1 $      EXTERNAL SORT
MATMOD  PHIAGEXT,EQEXINS,,,/PHIAGMPL,/16/
      PUNDMIG/////////C,Y,PUNCC $      DMIG FORMAT
OUTPUT2 PHIAGMPL,FREQHZEL,GENMEL/-1/UTUNIT3 $ WRITE TO OUTPUT2 FILE
JUMP  FINIS $      DONE
$
$ COME ERROR IF ERROR
$
LABEL  ERROR $      START ERROR PROCESSING
PRTPARM //0 $      PRINT PARAMETER TABLE
$
LABEL  FINIS $      FINISHED
$
END $

```


FILE 6. Listing of CORL8X.DMP

```
BEGIN $ PERFORM ORTHO, CROSS-ORTH AND MAC CHECKS          (CORL8)
$-----
$
$ THIS DMAP CAN BE USED IN EITHER TEST/ANALYSIS OR TAM/FEM
$ CORRELATION ANALYSES TO COMPUTE ORTHOGONALITY, CROSS-ORTHOGONALITY,
$ AND MODAL ASSURANCE CRITERION.
$
$
$ REQUIREMENTS TO USE THIS DMAP SEQUENCE -
$-----
$ DATA BASES -
$ THE FOLLOWING DATA BASE FILES MUST BE AVAILABLE -
$ -NONE
$-----
$ USER FILES -
$ THE USER MUST SUPPLY THE FOLLOWING INPUT FILES (OUTPUT4 FORMAT):
$ FOR011 - TAM MASS MATRIX (OPTION FOR MAC ONLY RUNS)
$ FOR012 - TAM MODE SHAPES
$ FOR013 - TEST MODE SHAPES (OR PARTITIONED FEM MODE SHAPES)
$
$-----
$ EXECUTIVE DECK -
$ INCLUDE THIS DMAP SEQUENCE (DO NOT USE A RIGID FORMAT)
$ DIAG 8,14,20 RECOMMENDED
$-----
$ CASE CONTROL DECK -
$ -NO SPECIAL REQUIREMENTS
$-----
$ BULK DATA DECK -
$
$ OPTIONAL PARAMETERS -
$
$ ORTHO  = 1  PERFORM ORTHOGONALITY CHECK (DEFAULT)
$        = -1 DO NOT PERFORM ORTHOGONALITY CHECK
$
$ CROSS  = 1  PERFORM CROSS-ORTHOGONALITY CHECK (DEFAULT)
$        = -1 DO NOT PERFORM CROSS-ORTHOGONALITY
$
$ MAC    = 1  DO NOT COMPUTE MODAL ASSURANCE CRITERION (DEFAULT)
$        = -1 COMPUTE MAC
$
$ MASS   = 1  MASS MATRIX IS PRESENT (DEFAULT)
$        = -1 NO TAM MASS MATRIX EXISTS
$
$ NORMTAM = 1  DO NOT NORMALIZE TAM MODES (DEFAULT)
$        = -1 NORMALIZE TAM MODES
$
$ NORMTEST = 1 DO NOT NORMALIZE TEST MODES (DEFAULT)
$        = -1 NORMALIZE TAM MODES
$
$ IP4FMT  = 1  READ INPUTT4 FILE IN BINARY FORMAT
$        = -1  READ INPUTT4 FILE IN BCD FORMAT (DEFAULT)
$
$-----
$ EXAMPLE NASTRAN DECK-
$
$ ID  CORL8,TAM
$ TIME 10
$ DIAG 8,14,20
```

File 6.

```

$ . THIS DMAP SEQUENCE
$ .
$ CEND
$ TITLE = CORL8 TAM TO TEST
$ $
$ BEGIN BULK
$ $
$ PARAM,ORTHO,-1      $ PERFORM ORTHOGONALITY CHECK
$ $
$ PARAM,CROSS,-1      $ PERFORM CROSS-ORTHOGONALITY CHECK
$ $
$ PARAM,MAC,-1        $ DO NOT PERFORM MAC CALCULATION
$ $
$ PARAM,MASS,-1       $ TAM MASS MATRIX IS PRESENT
$ $
$ PARAM,NORMTAM,-1    $ DO NOT RENORMALIZE TAM MODE SHAPES
$ $
$ PARAM,NORMTEST,-1   $ DO NOT RENORMALIZE TEST MODE SHAPES
$ $
$ PARAM,IP4FMT,1      $ READ INPUT4 IN BCD FORMAT
$ $
$ ENDDATA
$
$
$ -----
$ HISTORY DOCUMENTATION -
$
$ VERSION 1.0 15-JUN-90 ANDY FREED
$ - ORIGINAL VERSION (BASED ON DAN KAMMER'S XCORL8.DMP)
$
$ -----
$
PARAM //C,N,NOP/V,Y,UTUNIT1=11 $
PARAM //C,N,NOP/V,Y,UTUNIT2=12 $
PARAM //C,N,NOP/V,Y,UTUNIT3=13 $
PARAM //C,N,NOP/V,Y,MODEL=0 $
PARAM //C,N,NOP/V,Y,SEID=0 $      SET TO RESIDUAL STRUCTURE
PARAM //C,N,NOP/V,Y,CROSS=1 $     DO CROSS-ORTHOGONALITY
PARAM //C,N,NOP/V,Y,ORTHO=1 $     DO ORTHOGONALITY
PARAM //C,N,NOP/V,Y,MAC=-1 $      DO NOT COMPUTE MAC
PARAM //C,N,NOP/V,Y,MASS=1 $      MASS MATRIX EXISTS
PARAM //C,N,NOP/V,Y,NORMTAM=-1 $  DO NOT NORMALIZE TAM MODES
PARAM //C,N,NOP/V,Y,NORMTEST=-1 $ DO NOT NORMALIZE TEST MODES
PARAM //C,N,NOP/V,Y,IP4FMT=-1 $   INPUT4 FILES ARE BCD
$
$
$ READ IN TAM MASS MATRIX
$ -----
$
COND  NOMASS1,MASS $              JUMP IF NO MASS
INPUTT4 /MAA,,,/1/V,Y,UTUNIT1/-1/IP4FMT $  FORMATTED FILE
$
LABEL  NOMASS1 $
$
$ READ IN TAM MODE SHAPES
$ -----
$
INPUTT4 /TAMPHI,,,/1/V,Y,UTUNIT2/-1/IP4FMT $  FORMATTED FILE
$
$ NORMALIZE TAM MODE SHAPES WRT MASS

```

File 6. (cont.)

```

$ -----
$
COND  NONORM1,NORMTAM$          JUMP NOT TO NORMLZ
SMPYAD  TAMPHI,MAA,TAMPHI,,,/GMASST/3////1////6 $  TRANSPOSE FIRST PHI
DIAGONAL  GMASST/GG1T/C,Y,OPT=SQUARE/1. $  EXTRACT DIAGONAL
SOLVE  GG1T/GG1TINV $  TAKE INVERSE
DIAGONAL  GG1TINV/HGMASST/C,Y,OPT=SQUARE/5 $  TAKE SQUARE ROOT
MPYAD  TAMPHI,HGMASST,/TAMNRM $  SCALE MODES
JUMP  NOTAM1 $
LABEL  NONORM1 $
ADD  TAMPHI,/TAMNRM $  SET TAMPHI TO TAMNRM
LABEL  NOTAM1 $
$
$ READ IN TEST (OR FEM) MODES
$ -----
$
INPUTT4  /TPHI,,,/1/V,Y,UTUNIT3/-1/1P4FMT $  FORMATTED FILE
$
$  NORMALIZE TEST MODE SHAPES WRT MASS
$ -----
$
COND  NONORM2,NORMTEST $          JUMP NOT TO NORMLZ
COND  NONORM2,MASS $          JUMP IF NO MASS
$
SMPYAD  TPHI,MAA,TPHI,,,/GMASS/3////1////6 $  TRANSPOSE FIRST PHI
DIAGONAL  GMASS/GG1/C,Y,OPT=SQUARE/1. $  EXTRACT DIAGONAL
SOLVE  GG1/GG1INV $  TAKE INVERSE
DIAGONAL  GG1INV/HGMASS/C,Y,OPT=SQUARE/5 $  TAKE SQUARE ROOT
MPYAD  TPHI,HGMASS,/TESNRM $  SCALE MODES
JUMP  NONORM3 $
LABEL  NONORM2 $
ADD  TPHI,/TESNRM $  SET TPHI TO PHI
LABEL  NONORM3 $
$
$  PERFORM CORRELATION ANALYSES
$ -----
$
$
$
$ ORTHOGONALITY OF TEST MODES WRT TAM MASS
$ -----
$
COND  NORTHO,ORTHO $          JUMP IF NO ORTHOGONALITY
SMPYAD  TESNRM,MAA,TESNRM,,,/ORTHO/3////1////6 $  TRANSPOSE FIRST TESNRM
MATPRT  ORTHO// $  PRINT ORTHO
LABEL  NORTHO $
$
$ TAM/TEST CROSS-ORTHOGONALITY
$ -----
$
COND  NOCROSS3,CROSS $          JUMP IF NO CROSS-ORTHOG
SMPYAD  TAMNRM,MAA,TESNRM,,,/CROSSORTH/3////1////6 $  TRANSPOSE TAMNRM
MATPRT  CROSSORTH// $  PRINT CROSSORTH
LABEL  NOCROSS3 $
$
$
$ COMPUTE MODAL ASSURANCE CRITERION - TAM/TEST
$ -----
$
COND  NOMAC,MAC $          JUMP IF NO MAC
LABEL  DOMAC $          DO MAC LABEL
MPYAD  TAMNRM,TESNRM,/ORT/1 $  ORDINARY CROSSORTH
DIAGONAL  ORT/ORT2/WHOLE/V,Y,POWER=2. $  SQUARE EACH TERM
MPYAD  TAMNRM,TAMNRM,/TAMORT/1 $  TAM ORTHOGONALITY

```

File 6. (cont.)

```

MPYAD  TESNRM,TESNRM/TESORT/1 $      TEST ORTHOGONALITY
DIAGONAL TAMORT/TAMORTD/SQUARE $      STRIP DIAGONAL
DIAGONAL TESORT/TESORTD/SQUARE $      STRIP DIAGONAL
SOLVE  TAMORTD,/TAMINV $              INVERT
SOLVE  TESORTD,/TESINV $              INVERT
SMPYAD  TAMINV,ORT2,TESINV,,,MACM/3 $  COMPUTE MAC
MATPRT  MACM/$                        PRINT MATRIX
$
LABEL  NOMAC $                        END MAC CALC
$
END $
$

```

File 6. (cont.)

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FILE 7. Listing of PHIATEST.DMP

```

BEGIN $ CREATE MODAL DATA BLOCKS FROM UNIVERSAL FILE DATA (PHIATEST)
$-----
$
$ THIS DMAP SEQUENCE STORES THE TEST MODE FREQUENCIES AND SHAPES
$ IN A DATA BASE COMPATIBLE WITH A TAM. THE MODAL DATA CAN ALSO
$ BE WRITTEN TO AN OUTPUT4 FILE FOR ADDITIONAL PROCESSING.
$
$ IF REQUESTED BY PARAM EXTSORT, THE A-SET MODE SHAPES WILL BE
$ CONVERTED FROM INTERNAL TO EXTERNAL (NUMERICALLY ASCENDING) SORT.
$ THE MATRIX NAME WRITTEN TO THE OUTPUT4 FILE WILL CHANGE AS SHOWN
$ BELOW:
$
$ PHIA -> PHIAEXT
$
$ THE INTERNAL-TO-EXTERNAL SORT CONVERSION IS ONLY NEEDED IF THE
$ TAM RESIDUAL STRUCTURE IS INTERNALLY RESEQUENCED (NOT IN NUMERICALLY
$ ASCENDING ORDER) AND THE TAM MATRICES ARE REQUIRED TO BE IN EXTERNAL
$ SORT. THE INTERNAL-TO-EXTERNAL SORT CONVERSION IS USUALLY NOT
$ NEEDED FOR TAMS CREATED USING ONE OR MORE UPSTREAM SUPERELEMENTS.
$ IT WILL PROBABLY BE NEEDED WHEN THE TAM IS CREATED WITHOUT
$ SUPERELEMENTS.
$
$
$ THE MATRICES WRITTEN ARE AS FOLLOWS:
$
$ NAME DESCRIPTION NROW NCOL UNIT OPTIONAL?
$-----
$ PHIA(EXT) MODE SHAPES A-SET NMODE 11 NO
$ FREQHZ MODAL FREQUENCIES (HZ) NMODE 1 11 NO
$ GENMASS GENERALIZED MASS (DIAG ONLY) NMODE 1 11 NO
$
$
$ THE FOLLOWING INFORMATION IS WRITTEN TO THE NASTRAN OUTPUT FILE:
$
$ DESCRIPTION OPTIONAL? PARAM
$-----
$ GEOMETRY DATA FOR RESIDUAL STRUCTURE GRIDS YES GEOMPR1
$ SET ALLOCATION TABLES (USET TABLES) YES USETPR1
$ DIAGONAL TERMS OF THE REDUCED STIFFNESS MATRIX NO
$ DIAGONAL TERMS OF THE REDUCED MASS MATRIX NO
$ REAL EIGENVALUE SUMMARY NO
$ MODE SHAPES OF THE A-SET DOF YES (CASE CON)
$ RIGID BODY MASS MATRIX YES EFFMASS
$ UNIT RIGID BODY MODE SHAPES YES EFFMASS
$
$
$ REQUIREMENTS TO USE THIS DMAP SEQUENCE -
$-----
$ DATA BASES -
$ THE FOLLOWING DATA BASE FILES MUST BE AVAILABLE -
$ -TAM DATA BASE
$-----
$ USER FILES -
$ THE TEST DATA WILL BE WRITTEN TO FORTRAN UNIT 11 IN OUTPUT4
$ FORMAT. ALSO SEE PARAM,OP4FMT IN THE BULK DATA DECK.
$-----
$ EXECUTIVE DECK -
$ INCLUDE THIS DMAP SEQUENCE (DO NOT USE A RIGID FORMAT)
$ DIAG 8,14,20 RECOMMENDED
$-----

```

File 7.

\$ CASE CONTROL DECK -
 \$ A-SET MODE SHAPES MAY BE PRINTED BY AN "SVECTOR=ALL" REQUEST.

 \$ BULK DATA DECK -

\$ OPTIONAL PARAMETERS -

\$ PARAM,EXTSORT - IF 0, WRITE PHIA TO THE OUTPUT4 FILE IN
 \$ EXTERNAL SORT
 \$ (DEFAULT = -1 - PHIA WRITTEN IN INTERNAL SORT)

\$ PARAM,NORMTEST - IF 0, NORMALIZE THE TEST MODES TO UNITY ON
 \$ THE DIAGONAL OF THE ORTHOGONALITY MATRIX
 \$ (DEFAULT = -1 - DO NOT NORMALIZE THE TEST MODES)

\$ PARAM,OP4FMT - WRITE OUTPUT4 FILE IN BINARY (1) OR BCD
 \$ (.NE. 1) FORMAT.
 \$ (DEFAULT = 0 - WRITE BCD FORMAT)

 \$ EXAMPLE NASTRAN DECK-

\$ ID PHIA,TEST
 \$ TIME 10
 \$ DIAG 8,14,20

\$. THIS DMAP SEQUENCE

\$ CEND
 \$ TITLE = STORE TEST MODE SHAPES IN TAM-COMPATIBLE FORMAT
 \$ \$
 \$ BEGIN BULK
 \$ \$
 \$ WRITE THE PHIA DATA BLOCK TO THE OUTPUT4 FILE IN EXTERNAL SORT
 \$ \$
 \$ PARAM,EXTSORT,0
 \$ \$

\$. (TEST MODE DATA IN DMIG AND DMI FORMAT FROM UNVDM1)

\$ ENDDATA

 \$ HISTORY DOCUMENTATION -

\$ VERSION 1.0 ??-???-?? CHRIS FLANIGAN
 \$ - ORIGINAL VERSION
 \$ VERSION 2.0 02-OCT-90 CHRIS FLANIGAN
 \$ - ADD EXTERNAL SORT OPTION
 \$ - WRITE DATA BLOCKS TO THE OUTPUT4 FILE AS DONE BY WTTAM
 \$ - ADD DOCUMENTATION
 \$ VERSION 3.0 13-NOV-90 CHRIS FLANIGAN
 \$ - ADD TEST MODES NORMALIZATION OPTION
 \$ - ENHANCE DOCUMENTATION

 \$23456789012345678901234567890123456789012345678901234567890123456789012
 \$ 1 2 3 4 5 6 7

\$ SET DEFAULT VALUES

\$
 \$ PARAM //C,N,NOP/V,Y,EXTSORT=-1 \$ EXTERNAL SORT OPTION
 \$ PARAM //C,N,NOP/V,Y,NORMTEST=-1 \$ NORMALIZATION OPTION

File 7. (cont.)

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```

PARAM //C,N,NOP/V,Y,OP4FMT=0 $      OUTPUT4 FORMAT
$
$ CREATE A NEW DATA BASE
$
DBMGR //0/V,Y,DBCLEAN=0/V,Y,DBNBLKS=20000//
      V,Y,DBINIT=0/V,Y,DBNAME=DB01 $
$
$ CREATE LAMA TABLE FROM DMI "LAMADMI"
$
LAMX LAMADMI,/LAMA/ $
OPF LAMA/ $
$
$ CREATE MODES SHAPE MATRIX FROM DMIG "PHIG"
$
DBFETCH /GPLS,EQEXINS,SILS,USET,MAA/0/0 $      FETCH TAM DATA
PARAML USET//USET/////C,N,A/V,N,NOASET/
      C,N,G/V,N,NOGSET $      NO. OF DOF IN SETS
MTRXIN „MATPOOL,EQEXINS,SILS,/PHIG,,/V,N,NOGSET/
      S,N,NOPHIG $      READ TEST MODE SHAPES
$
$ PARTITION TO A-SET DOF
$
VEC USET/VGAX/G/A/COMP $      G = A / COMP
PARTN PHIG,,VGAX/PHIA1,PHIX1,,/1 $      ROW PARTITION
$
$ NORMALIZE TO UNITY ON THE DIAGONAL OF THE ORTHOGONALITY MATRIX
$
EQUIV PHIA1,PHIA/NORMTEST $      EQUIV IF NORMTEST.LT.0
EQUIV PHIX1,PHIX/NORMTEST $      EQUIV IF NORMTEST.LT.0
COND DNNORM,NORMTEST $      SKIP IF NORMTEST.LT.0
SMPYAD PHIA1,MAA,PHIA1,,,/GENMASS/3/////6 $ TRANSPOSE FIRST PHI
DIAGONAL GENMASS/GG1/C,Y,OPT=SQUARE/1. $      EXTRACT DIAGONAL
PARAML GG1/TRAILER/1/V,N,NOMODES $      NUMBER OF MODES
MATGEN „/HH/1/NOMODES $      IDENTIFY MATRIX
SOLVE GG1,HH/GG1INV $      INVERT
DIAGONAL GG1INV/HGMASS/C,Y,OPT=SQUARE/5 $      SQUARE ROOT
MPYAD PHIA1,HGMASS,/PHIA $      SCALE MODES
MPYAD PHIX1,HGMASS,/PHIX $      SCALE MODES
LABEL DNNORM $      DONE
MATGPR GPLS,USET,SILS,PHIA/H/A $      PRINT A-SET MODES
$
$ PRINT THE X-SET TO CHECK FOR TEST DOF WHICH DO NOT CORRESPOND
$ TO THE A-SET DOF
$
MERGE „,PHIX,,,VGAX/PHIGX/1 $
MATGPR GPLS,USET,SILS,PHIGX/H/G $
$
$ CHECK THE A-SET FOR ANY DOF WHICH ARE NOT DEFINED IN THE TEST
$ DATA
$
MATGEN „VA/6/NOASET/0/NOASET $      1'S FOR A-SET
MATMOD PHIA,,,,/PHIAMAX,/6 $      MAX FOR EACH ROW
PARTN VA,,PHIAMAX/VZERO,VNZ,,/1 $      ROW PARTITION
MERGE VZERO,,,PHIAMAX/PHIAZERO/1 $      ROW MERGE
MATGPR GPLS,USET,SILS,PHIAMAX/H/A $      PRINT MAX VALUES
MATGPR GPLS,USET,SILS,PHIAZERO/H/A $      PRINT ZERO VALUES
$
$ STORE THE MODAL DATA
$
DBSTORE LAMA,PHIA/0/0 $      STORE IN DATA BASE
$
$ WRITE THE TEST MODE SHAPE MATRICES IN INTERNAL
$ OR EXTERNAL SORT

```

File 7. (cont.)

```

$
COND INTERN1,EXTSORT $ SKIP IF EXTSORT .LE. -1
MATGEN EQEXINS/INTEXT/9/0/NOGSET $ INTERNAL-TO-EXTERNAL
MERGE PHIA,,,,VGAX/PHIAG/1 $ ROW MERGE TO G-SET
MPYAD INTEXT,PHIAG,/PHIAGEXT/1 $ EXTERNAL SORT
MPYAD INTEXT,VGAX,/VGAXEXT/1 $ EXTERNAL SORT
PARTN PHIAGEXT,,VGAXEXT/PHIAEXT,,,/1 $ ROW PARTN TO A-SET
OUTPUT4 PHIAEXT//1/11/OP4FMT $ TAM MODE SHAPES
JUMP DNINEX1 $ JUMP TO LABEL DNINEX1
$
LABEL INTERN1 $ INTERNAL SORT
OUTPUT4 PHIA//1/11/OP4FMT $ TAM MODE SHAPES
LABEL DNINEX1 $ DONE WITH INT-EXT SORT
$
$ WRITE THE TEST FREQUENCIES (HZ) AND GENERALIZED MASS
$
LAMX ,,LAMA/LAMAMAT/-1 $ MAKE MATRIX FROM LAMA
MATMOD LAMAMAT,,,,/FREQHZ/1/3 $ COL 3 = FREQ. (HZ)
MATMOD LAMAMAT,,,,/GENMASS/1/4 $ COL 4 = GEN. MASS
OUTPUT4 FREQHZ,GENMASS/0/11/OP4FMT $ TAM FREQ AND GEN. MASS
$
END $

```

File 7. (cont.)

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Appendix III

Data files associated with ten-bay model

FILE 8. Listing of TENBAYFEM.DAT

```
1. ID VIBRATION ANALYSIS,TEN BAY TRUSS
2. $
3. $
4. $ THIS MSC NASTRAN FEM SOLVES FREQUENCIES
5. $AN D MODE SHAPES FOR A TEN BAY TRUSS--
6. $CANT ILEVERED TO THE WALL WITH METAL PLATE ON THE END
7. $METAL PLATE REFINED (7/22)
8. $
9. $ TEN BAY TRUSS SOLUTION 63
10. $ THIS SOLUTION STARTS WITH THE DATABASE FROM SOLUTION 64
11. $ (DIFFERENTIAL STIFFNESS EFFECT)
12. $
13. $ -----
14. SOL 63 $ NORMAL MODES
15. TIME 60 $ 60 CPU MINUTES (VAX 11/780 TIMING)
16. DIAG 8 $ PRINT MATRIX TRAILERS
17. DIAG 20 $ PRINT DATA BASE FETCH/STORE MESSAGES
18. $
19. $ ALTER RF63D307.DAT
20. $ OUTPUT MODE SHAPES IN OUTPUT2 FILES
21. $ MODE SHAPES IN BASIC COORDINATES IN UNIT 12
22. $ COORDINATE SYSTEMS
23. $ -----
24. $ REPLACE THE NEXT LINE WITH ALTER RF63D307
25. $
26. &RF63D307.DAT
27. ECHOON
28. $
29. CEND
30. $
31. ECHO = BOTH
32. $
33. TITLE = TEN BAY TRUSS NORMAL MODES
34. SUBTITLE = NORMAL MODES - ORIGINAL RUN
35. $
36. SEKR = ALL
37. SEMR = ALL
38. $
39. SPC = 20
40. $
41. DISP = ALL $ RECOVER BUT DO NOT PRINT MODE SHAPES
42. $
43. METHOD = 50 $ COMPONENT MODES TO 150 HZ
44. $
45. $
46. BEGIN BULK
47. $
48. $ PARAMETER CARDS
49. $ -----
50. $
51. PARAM,AUTOSPC,YES
52. PARAM,DBNBLKS,33000
53. PARAM,GRDPNT,0
54. PARAM,USETPRT,0
55. PARAM,COUPMASS,1
56. PARAM,MAXRATIO,5.0E6
57. $
58. $ EIGENVALUE SOLUTION DATA
59. $ -----
60. EIGRL,50,1.0,150.0
```

File 8.

61. \$
62. \$ BULK DATA
63. \$ -----
64. \$ REPLACE THE NEXT LINE WITH BULK CARDS
65. \$
66. &TENBAYFEM.BLK
67. \$
68. \$
69. ENDDATA

FILE 9. Listing of the Bulk Data Deck

```
$-----
$BULK DATA DECK FOLLOWS
$-----
$
$GRAVITY LOAD IN +Z
$GRAV,103,,386.1,0.0,0.0,1.0
$GRAVITY LOAD IN -Y
$GRAV,103,,386.1,0.0,-1.0,0.0
$
$-----
$
$PROPERTIES FOR TIP PLATE CONNECTING STRUTS
$
PBAR,101,103,1.0,1.0,1.0,1.0
MAT1,103,10.E9,,3,.000001
$
$PROPERTIES FOR LONGERONS AND DIAGONALS
$
PROD,201,102,,1139,.0169
PROD,202,204,,1139,.0169
MAT1,102,10.E6,,3,.0001894
MAT1,111,10.E6,,3,.0002591
MAT1,112,30.E6,,3,.0007513
MAT1,204,10.E6,,3,.0002034
$
$TIP PLATE ELEMENTS
$
cquad4,401,501,45,52,56,54,0.
cquad4,402,501,52,56,58,50,0.
cquad4,403,501,50,58,60,48,0.
cquad4,404,501,58,60,62,64,0.
cquad4,405,501,58,64,66,56,0.
cquad4,406,501,56,66,68,54,0.
cquad4,407,501,46,70,66,68,0.
cquad4,408,501,70,72,64,66,0.
cquad4,409,501,72,47,62,64,0.
cquad4,420,502,45,52,56,54,0.
cquad4,421,502,52,56,58,50,0.
cquad4,422,502,50,58,60,48,0.
cquad4,423,502,58,60,62,64,0.
cquad4,424,502,58,64,66,56,0.
cquad4,425,502,56,66,68,54,0.
cquad4,426,502,46,70,66,68,0.
cquad4,427,502,70,72,64,66,0.
cquad4,428,502,72,47,62,64,0.
pshell,501,111,.375,111
pshell,502,112,.5,112
$
$CANTILEVERED BOUNDARY CONDITIONS
$
SPC1,20,123456,1,2,3,4
$
$TRUSS GRID POINTS
$
GRID,1,,0.,0.,0.
GRID,2,,0.,0.000,19.700
GRID,3,,0.,19.7,19.7
GRID,4,,0.,19.700,0.000
GRID,5,,19.7,0.,0.
GRID,6,,19.7,0.000,19.700
GRID,7,,19.7,19.7,19.7
```

File 9.

GRID,8,,19.7,19.700,0.000
 GRID,9,,39.4,0.,0.
 GRID,10,,39.4,0.000,19.700
 GRID,11,,39.4,19.7,19.7
 GRID,12,,39.4,19.700,0.000
 GRID,13,,59.1,0.,0.
 GRID,14,,59.1,0.000,19.700
 GRID,15,,59.1,19.7,19.7
 GRID,16,,59.1,19.700,0.000
 GRID,17,,78.8,0.,0.
 GRID,18,,78.8,0.000,19.700
 GRID,19,,78.8,19.7,19.7
 GRID,20,,78.8,19.700,0.000
 GRID,21,,98.5,0.,0.
 GRID,22,,98.5,0.000,19.700
 GRID,23,,98.5,19.7,19.7
 GRID,24,,98.5,19.700,0.000
 GRID,25,,118.2,0.,0.
 GRID,26,,118.2,0.000,19.700
 GRID,27,,118.2,19.7,19.7
 GRID,28,,118.2,19.700,0.000
 GRID,29,,137.9,0.,0.
 GRID,30,,137.9,0.000,19.700
 GRID,31,,137.9,19.7,19.7
 GRID,32,,137.9,19.700,0.000
 GRID,33,,157.6,0.,0.
 GRID,34,,157.6,0.000,19.700
 GRID,35,,157.6,19.7,19.7
 GRID,36,,157.6,19.700,0.000
 GRID,37,,177.3,0.,0.
 GRID,38,,177.3,0.000,19.700
 GRID,39,,177.3,19.7,19.7
 GRID,40,,177.3,19.700,0.000
 GRID,41,,197.0,0.,0.
 GRID,42,,197.0,0.000,19.700
 GRID,43,,197.0,19.7,19.7
 GRID,44,,197.0,19.700,0.000
 GRID,45,,198.125,0.,0.
 GRID,46,,198.125,0.000,19.700
 GRID,47,,198.125,19.7,19.7
 GRID,48,,198.125,19.700,0.000
 \$
 \$PLATE GRID POINTS
 \$
 GRID,52,,198.125,6.567,0.000
 GRID,50,,198.125,13.134,0.000
 GRID,54,,198.125,0.000,6.567
 GRID,56,,198.125,6.567,6.567
 GRID,58,,198.125,13.134,6.567
 GRID,60,,198.125,19.700,6.567
 GRID,62,,198.125,19.700,13.134
 GRID,64,,198.125,13.134,13.134
 GRID,66,,198.125,6.567,13.134
 GRID,68,,198.125,0.000,13.134
 GRID,70,,198.125,6.567,19.700
 GRID,72,,198.125,13.134,19.700
 \$
 \$TRUSS ELEMENTS
 \$
 CROD,1,201,1,2
 CROD,2,201,2,3
 CROD,3,201,3,4
 CROD,4,201,1,4

File 9. (cont.)

CROD,5,201,5,6
CROD,6,201,6,7
CROD,7,201,7,8
CROD,8,201,5,8
CROD,9,201,1,5
CROD,10,201,2,6
CROD,11,201,3,7
CROD,12,201,4,8
CROD,13,202,2,4
CROD,14,202,2,7
CROD,15,202,6,8
CROD,16,202,4,5
CROD,17,202,4,7
CROD,18,202,2,5
CROD,19,201,6,10
CROD,20,201,9,10
CROD,21,201,5,9
CROD,22,201,7,11
CROD,23,201,8,12
CROD,24,201,11,12
CROD,25,201,10,11
CROD,26,201,9,12
CROD,27,202,5,10
CROD,28,202,7,12
CROD,29,202,7,10
CROD,30,202,10,12
CROD,31,202,5,12
CROD,32,201,10,14
CROD,33,201,9,13
CROD,34,201,13,14
CROD,35,201,11,15
CROD,36,201,12,16
CROD,37,201,15,16
CROD,38,201,14,15
CROD,39,201,13,16
CROD,40,202,10,13
CROD,41,202,12,15
CROD,42,202,10,15
CROD,43,202,12,13
CROD,44,202,14,16
CROD,45,201,14,18
CROD,46,201,13,17
CROD,47,201,17,18
CROD,48,201,15,19
CROD,49,201,16,20
CROD,50,201,19,20
CROD,51,201,18,19
CROD,52,201,17,20
CROD,53,202,13,18
CROD,54,202,15,20
CROD,55,202,15,18
CROD,56,202,13,20
CROD,57,202,18,20
CROD,58,201,18,22
CROD,59,201,17,21
CROD,60,201,19,23
CROD,61,201,20,24
CROD,62,201,23,24
CROD,63,201,22,23
CROD,64,201,21,24
CROD,65,201,21,22
CROD,66,202,18,21
CROD,67,202,20,23

File 9. (cont.)

CROD,68,202,18,23
CROD,69,202,20,21
CROD,70,202,22,24
CROD,71,201,22,26
CROD,72,201,21,25
CROD,73,201,25,26
CROD,74,201,23,27
CROD,75,201,24,28
CROD,76,201,26,27
CROD,77,201,27,28
CROD,78,201,25,28
CROD,79,202,21,26
CROD,80,202,23,26
CROD,81,202,21,28
CROD,82,202,23,28
CROD,83,202,26,28
CROD,84,201,26,30
CROD,85,201,25,29
CROD,86,201,30,31
CROD,87,201,31,32
CROD,88,201,29,32
CROD,89,201,29,30
CROD,90,201,27,31
CROD,91,201,28,32
CROD,92,202,26,29
CROD,93,202,26,31
CROD,94,202,28,29
CROD,95,202,28,31
CROD,96,202,30,32
CROD,97,201,29,33
CROD,98,201,30,34
CROD,99,201,34,35
CROD,100,201,33,34
CROD,101,201,35,36
CROD,102,201,33,36
CROD,103,201,32,36
CROD,104,201,31,35
CROD,105,202,29,34
CROD,106,202,31,34
CROD,107,202,29,36
CROD,108,202,31,36
CROD,109,202,34,36
CROD,110,201,33,37
CROD,111,201,34,38
CROD,112,201,36,40
CROD,113,201,35,39
CROD,114,201,37,40
CROD,115,201,37,38
CROD,116,201,38,39
CROD,117,201,39,40
CROD,118,202,34,37
CROD,119,202,36,39
CROD,120,202,34,39
CROD,121,202,36,37
CROD,122,202,38,40
CROD,123,201,37,41
CROD,124,201,38,42
CROD,125,201,40,44
CROD,126,201,39,43
CROD,127,201,41,44
CROD,128,201,41,42
CROD,129,201,42,43
CROD,130,201,43,44

File 9. (cont.)

CROD,131,202,37,42
 CROD,132,202,39,44
 CROD,133,202,39,42
 CROD,134,202,37,44
 CROD,135,202,42,44
 \$
 \$CONNECTING STRUCT ELEMENTS
 \$
 CBAR,136,101,44,48,0.,0.,1.,1
 CBAR,137,101,43,47,0.,0.,1.,1
 CBAR,138,101,42,46,0.,0.,1.,1
 CBAR,139,101,41,45,0.,0.,1.,1
 \$
 \$CONM2'S FOR JOINT MASSES
 \$ ADD MASS FOR ACCELS AND CABLING
 \$
 CONM2,301,1,,.001821
 CONM2,302,2,,.002917
 CONM2,303,3,,.001821
 CONM2,304,4,,.002917
 CONM2,305,5,,.003648
 CONM2,306,6,,.002551
 CONM2,307,7,,.003648
 CONM2,308,8,,.002551
 CONM2,309,9,,.002186
 CONM2,310,10,,.004013
 CONM2,311,11,,.002186
 CONM2,312,12,,.004013
 CONM2,313,13,,.003648
 CONM2,314,14,,.002551
 CONM2,315,15,,.003648
 CONM2,316,16,,.002551
 CONM2,317,17,,.002186
 CONM2,318,18,,.004013
 CONM2,319,19,,.002186
 CONM2,320,20,,.004013
 CONM2,321,21,,.003648
 CONM2,322,22,,.002551
 CONM2,323,23,,.003648
 CONM2,324,24,,.002551
 CONM2,325,25,,.002186
 CONM2,326,26,,.004013
 CONM2,327,27,,.002186
 CONM2,328,28,,.004013
 CONM2,329,29,,.003648
 CONM2,330,30,,.002551
 CONM2,331,31,,.003648
 CONM2,332,32,,.002551
 CONM2,333,33,,.002186
 CONM2,334,34,,.004013
 CONM2,335,35,,.002186
 CONM2,336,36,,.004013
 CONM2,337,37,,.003648
 CONM2,338,38,,.002551
 CONM2,339,39,,.003648
 CONM2,340,40,,.002551
 CONM2,341,41,,.001821
 CONM2,342,42,,.002917
 CONM2,343,43,,.001821
 CONM2,344,44,,.002917
 CONM2,345,45,,.0009719
 CONM2,346,46,,.0009719
 CONM2,347,47,,.0009719

File 9. (cont.)

CONM2,348,48,,.0009719
CONM2,350,50,,.000832
CONM2,352,52,,.000832
CONM2,354,54,,.000832
CONM2,360,60,,.000832
CONM2,362,62,,.000832
CONM2,368,68,,.000832
CONM2,370,70,,.000832
CONM2,372,72,,.000832
\$END OF BULK DATA

File 9. (cont.)

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FILE 10. Listing of TENBAYFEM.COM

```
1.    $! ASSIGNMENT FILE FOR FEM OF TENBAY ORIGINAL NORMAL MODES RUN (SOL63)
2.    $!
3.    $! FEM DATABASE
4.    $! ASSIGN TENBAYFEM.D01      DB01      ! O
5.    $!
6.    $! MODE SHAPES FOR SEMCOMB (BASIC CORD)
7.    $! ASSIGN TENBAYFEM.U11      FOR011    ! O
8.    $!
9.    $! MODE SHAPES FOR SEMCOMB (DISPLACEMENT CORD)
10.   $! ASSIGN TENBAYFEM.U12      FOR012    ! O
```

FILE 11. Listing of TENBAY14.DAT

```

1. ID VIBRATION ANALYSIS,TEN BAY TRUSS
2. $
3. $ TEN BAY TRUSS SOLUTION 63
4. $ CANTILEVERED TO THE WALL WITH METAL PLATE AT THE FREE END
5. $ METAL PLATE REFINED (7/22)
6. $
7. $ -----
8. $
9. SOL 63 $ NORMAL MODES
10. TIME 60 $ 60 CPU MINUTES (VAX 11/780 TIMING)
11. DIAG 8 $ PRINT MATRIX TRAILERS
12. DIAG 20 $ PRINT DATA BASE FETCH/STORE MESSAGES
13. $ -----
14. $ ADD EITHER THE ALTER IRSRED63.ALT FOR THE IRS REDUCTION
15. $ OR THE ALTER HRED63.ALT FOR THE HYBRID REDUCTION
16. $
17. $ DO NOT USE BOTH AT THE SAME TIME
18. $ -----
19. $&IRSRED63.ALT $ FOR IRS REDUCTION
20. $&HRED63.ALT $ FOR HYBRID REDUCTION
21. $
22. ECHOON
23. $
24. CEND
25. $
26. ECHO = BOTH
27. $
28. TITLE = TEN BAY TRUSS NORMAL MODES
29. SUBTITLE = NORMAL MODES - ORIGINAL RUN
30. $
31. SEKR = ALL
32. SEMR = ALL
33. $
34. SPC = 20
35. $
36. DISP = ALL $ RECOVER BUT DO NOT PRINT MODE SHAPES
37. $
38. METHOD = 50 $ COMPONENT MODES TO 150 HZ
39. $
40. $
41. BEGIN BULK
42. $
43. $ PARAMETER CARDS
44. $ -----
45. $
46. PARAM,AUTOSPC,YES
47. PARAM,DBNBLKS,33000
48. PARAM,GRDPNT,0
49. PARAM,USETPRT,0
50. PARAM,COUPMASS,1
51. PARAM,MAXRATIO,5.0E6
52. $
53. $ EIGENVALUE SOLUTION DATA
54. $ -----
55. $
56. EIGRL,50,1.0,150.0
57. $
58. $ BULK DATA
59. $ -----
60. $ REPLACE THE NEXT LINE WITH BULK DATA CARDS

```

File 11.

61. \$
62. &TENBAYFEM.BLK
63. \$
64. \$ A-SET DOF
65. \$ -----
66. \$ INSERT ASET CARDS (DEGREES OF FREEDOM TO BE RETAINED)
67. \$
68. &ASET14.AST
69. \$
70. ENDDATA

FILE 12. Listing of ASET14.AST

```
$      FILENAME ASET14.AST
$
$ .....
$
$      REDUCED TEST CONFIGURATION
$
$      14 DOFS
$ .....
$
$
ASET1,23,21,22
ASET1,2,24
ASET1,3,23
ASET1,23,45,46,47,48
```

FILE 13. Listing of TENBAY14.COM

```
1. $! ASSIGNMENT FILE FOR TENBAY14 RUN - SOL 63
2. $!
3. $! TAM DATABASE
4. $! ASSIGN TENBAY14.D01 DB01 ! O
5. $!
```

FILE 14. Listing of WTTAM14.DAT

```
1. ID WRITE,TAM
2. $
3. $ FILE TO WRITE MASS & MODE SHAPE MATRICES OF TAM
4. $
5. $ DB01 = TAM DATA BASE
6. $ FOR011 = OUTPUT4 FILE CONTAINING MASS MATRIX (OUTPUT)
7. $ FOR012 = OUTPUT4 FILE CONTAINING MODE SHAPES (OUTPUT)
8. $
9. TIME 60 $ 60 CPU MINUTES (VAX 11/750 TIMING)
10. DIAG 8 $ PRINT MATRIX TRAILERS
11. DIAG 20 $ PRINT DATA BASE FETCH/STORE MESSAGES
12. $
13. $ WRITE TAM TO OUTPUT4 FILES
14. $ -----
15. $ REPLACE NEXT LINE WITH THE DMAP, WTTAM.DMP
16. $
17. &WTTAM.DMP
18. $
19. CEND
20. $
21. TITLE = 14 DOFS TENBAY TEST CONFIGURATION
22. SUBTITLE = WRITE TAM TO OUTPUT4 FILE
23. $
24. ECHO= NONE
25. $
26. BEGIN BULK
27. $
28. $ DO NOT FORM RB MASS MATRIX AND UNIT RB MODES
29. PARAM EFFMASS -1
30. $
31. $ DO NOT PRINT GEOMETRY DATA
32. PARAM GEOMPRT -1
33. $
34. $ PRINT USET TABLE
35. PARAM USETPRT 0
36. $
37. $ PRINT MODE SHAPES IN EXTERNAL SORT
38. PARAM EXTSORT 1
39. $
40. ENDDATA
```


FILE 15. Listing of WTTAM14.COM

```
1. $ | ASSIGNMENT FILE TO WRITE MASS & MODE SHAPE MATRICES OF TAM
2. $ |
3. $ | TAM DATABASE
4. $ | -----
5. $ ASSIGN TENBAY14.D01 DB01 ! I
6. $ |
7. $ | OUTPUT - OUTPUT 4 FILE CONTAINING MASS
8. $ | -----
9. $ ASSIGN TAMMASS14.OP4 FOR011 ! O
10. $ |
11. $ | OUTPUT - OUTPUT 4 FILE CONTAINING MODE SHAPES
12. $ | -----
13. $ ASSIGN TAMMODES14.OP4 FOR012 ! O
```

FILE 16. Listing of PARTNMODA14.DAT

```
1. ID PARTNA,FEM
2. $
3. $ PARTITIONING FEM MODE SHAPES TO TAM DOFS
4. $
5. $ INPUT: TENBAYFEM.OP4 ON FOR011
6. $ OUTPUT: TENBAYFEM_PARTNA_1.OP4 ON FOR012
7. $
8. TIME 30 $ 30 CPU MINUTES (VAX 11/750 TIMING)
9. DIAG 8 $ PRINT MATRIX TRAILERS
10. DIAG 20 $ PRINT DATA BASE FETCH/STORE MESSAGES
11. $
12. $ PARTITION FEM MODE SHAPES
13. $ -----
14. $ REPLACE THE FOLLOWING LINE WITH DMAP PARTNMODAX.DMP
15. $
16. &PARTNMODX.DMP
17. $
18. CEND
19. $
20. TITLE = 14 DOFS TENBAY TEST CONFIGURATION
21. SUBTITLE = PARTITION FEM MODE SHAPES TO TAM A-SET DOF
22. $
23. ECHO = NONE
24. $
25. BEGIN BULK
26. $
27. $ BULK DATA
28. $ -----
29. $ REPLACE THE FOLLOWING LINE WITH BULK DATA DECK
30. $
31. &TENBAY.BLK
32. $
33. $ A-SET DOF
34. $ -----
35. $ INSERT A-SET CARDS (DOFS TO BE RETAINED)
36. $ IN PLACE OF THE NEXT LINE
37. $
38. &ASET14.AST
39. $
40. ENDDATA
```

FILE 17. Listing of PARTNMODA14.COM

```
1.    $! ASSIGNMENT FILE FOR PARTITIONING FEM MODE SHAPES TO TAM DOFS
2.    $!
3.    $! INPUT - FEM MODE SHAPES (FROM SEMCOMB)
4.    $ ASSIGN TENBAYFEM.OP4          FOR011 !!
5.    $!
6.    $! OUTPUT - PARTITIONED FEM MODE SHAPES (TAM A-SET SIZE)
7.    $ ASSIGN TENBAY14_PARTNA.OP4    FOR012 !O
```

FILE 18. Listing of CORL8TAM14.DAT

```
1. ID TAM,XCORL8
2. $
3. $ CORRELATING TAM & FEM MODELS
4. $
5. $ USER ASSIGNED FILES:
6. $ -----
7. $ FOR011 = TAM MASS MATRIX: OUTPUT4 FILE (BCD FORMAT)
8. $ FOR012 = TAM MODE SHAPES: OUTPUT4 FILE (BCD FORMAT)
9. $ FOR013 = TEST (OR FEM) MODE SHAPES: OUTPUT4 FILE (BCD FORMAT)
10. $
11. TIME 60 $ 60 CPU MINUTES (VAX 11/750 TIMING)
12. DIAG 8 $ PRINT MATRIX TRAILERS
13. DIAG 20 $ PRINT DATA BASE FETCH/STORE MESSAGES
14. $
15. $ PERFORM FEM/TAM CORRELATION
16. $ -----
17. $ REPLACE THE NEXT LINE WITH THE DMAP CORL8X.DMP
18. $
19. &CORL8X.DMP
20. $
21. CEND
22. $
23. TITLE = 14 DOFS TEST CONFIGURATION
24. SUBTITLE = CORRELATE TAM TO FEM
25. $
26. ECHO= NONE
27. $
28. BEGIN BULK
29. $
30. PARAM,ORTHO,1 $ PERFORM ORTHOGONALITY CHECK
31. $
32. PARAM,CROSS,1 $ PERFORM CROSS-ORTHOGONALITY CHECK
33. $
34. PARAM,MAC,1 $ DO PERFORM MAC CALCULATION
35. $
36. PARAM,MASS,1 $ TAM MASS MATRIX IS PRESENT
37. $
38. PARAM,NORMTAM,-1 $ DO NOT RENORMALIZE TAM MODE SHAPES
39. $
40. PARAM,NORMTEST,-1 $ DO NOT RENORMALIZE TEST MODE SHAPES
41. $
42. ENDDATA
```

FILE 19. Listing of CORL8TAM14.COM

```
1.    $! ASSIGNMENT FILES CORRELATING TAM & FEM MODELS
2.    $!
3.    $! TAM MASS MATRIX
4.    $!
5.    $ ASSIGN TAMMASS14.OP4          FOR011 ! I
6.    $!
7.    $! TAM MODE SHAPES
8.    $!
9.    $ ASSIGN TAMMODES14.OP4        FOR012 ! I
10.   $!
11.   $! FEM MODES (PARTITIONED TO TAM DOF)
12.   $!
13.   $ ASSIGN TENBAY14_PARTNA.OP4   FOR013 ! I
14.   $!
```

FILE 20. Listing of CORL8STAM.OUT

1 14 DOFS TEST CONFIGURATION
CORRELATE GUYAN TAM TO FEM

INTERMEDIATE MATRIX ... ORTHO

	1	2	3	4	5	6	7	8	9
1	100	0	0	3	-1	0	0	20	-8
2	0	100	0	1	4	0	-1	7	24
3	0	0	97	1	0	0	-12	0	0
4	3	1	1	87	-1	1	3	-13	1
5	-1	4	0	-1	83	1	3	0	-25
6	0	0	0	1	1	0	0	0	0
7	0	-1	-12	3	3	0	69	-1	-1
8	20	7	0	-13	0	0	-1	7	0
9	-8	24	0	1	-25	0	-1	0	14

1 14 DOFS TEST CONFIGURATION
CORRELATE GUYAN TAM TO FEM

INTERMEDIATE MATRIX ... CROSSORT

	1	2	3	4	5	6	7	8	9
1	-100	0	0	-3	1	0	0	-20	8
2	0	-100	0	-1	-4	0	1	-7	-24
3	0	0	-98	-1	-1	0	13	0	0
4	0	0	0	-93	5	-1	-3	15	-2
5	0	0	0	4	91	1	3	-1	-28
6	0	0	0	0	0	-1	82	0	0

1 14 DOFS TEST CONFIGURATION
CORRELATE GUYAN TAM TO FEM

INTERMEDIATE MATRIX ... MACM

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	49	3
2	0	100	0	0	0	0	0	5	27
3	0	0	100	0	2	0	2	0	2
4	1	0	0	100	0	13	0	53	0
5	0	1	2	0	100	16	7	0	77
6	0	0	0	0	7	1	98	0	6

FILE 21. Listing of CORL8ITAM.OUT

1 14 DOFS TEST CONFIGURATION
CORRELATE IRS TAM TO FEM

INTERMEDIATE MATRIX ... ORTHO

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	9	-3
2	0	100	0	0	0	1	0	5	14
3	0	0	100	0	0	0	-1	-1	-1
4	0	0	0	100	0	0	0	-2	-1
5	0	0	0	0	99	-1	1	-2	-12
6	0	1	0	0	-1	55	-1	-28	-43
7	0	0	-1	0	1	-1	95	0	1
8	9	5	-1	-2	-2	-28	0	35	16
9	-3	14	-1	-1	-12	-43	1	16	52

1 14 DOFS TEST CONFIGURATION
CORRELATE IRS TAM TO FEM

INTERMEDIATE MATRIX ... CROSSORT

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	9	-3
2	0	100	0	0	0	1	0	5	14
3	0	0	100	0	0	0	-1	-1	-1
4	0	0	0	-100	0	0	0	2	1
5	0	0	0	0	-100	1	-1	2	12
6	0	0	0	0	0	74	-2	-37	-57
7	0	0	0	0	0	0	97	-1	0
8	0	0	0	0	0	-1	0	45	-18
9	0	0	0	0	0	3	3	-7	-36

1 14 DOFS TEST CONFIGURATION
CORRELATE IRS TAM TO FEM

INTERMEDIATE MATRIX ... MACM

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	49	3
2	0	100	0	0	0	0	0	5	27
3	0	0	100	0	2	0	2	0	2
4	0	0	0	100	0	15	0	51	0
5	0	0	2	0	100	15	7	0	75
6	0	0	0	7	9	96	0	4	7
7	0	0	1	0	7	0	100	0	6
8	41	0	1	51	13	1	1	81	18
9	0	22	0	2	77	8	6	4	93

File 21.

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FILE 22. Listing of CORL8HTAM.OUT

1 TEN BAY TRUSS NORMAL MODES HYBRID REDUCTION NORMAL MODES - HYBRID TAM

INTERMEDIATE MATRIX ... ORTHO

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	0	0
2	0	100	0	0	0	0	0	0	0
3	0	0	100	0	0	0	0	0	0
4	0	0	0	100	0	0	0	0	0
5	0	0	0	0	100	0	0	0	0
6	0	0	0	0	0	100	0	0	0
7	0	0	0	0	0	0	100	0	0
8	0	0	0	0	0	0	0	100	0
9	0	0	0	0	0	0	0	0	100

1 TEN BAY TRUSS NORMAL MODES HYBRID REDUCTION NORMAL MODES - HYBRID TAM

INTERMEDIATE MATRIX ... XORTHO

	1	2	3	4	5	6	7
1	-95	-32	1	0	1	0	0
2	-32	95	-1	0	-1	0	0
3	0	1	98	4	14	0	0
4	0	0	-7	97	21	0	3
5	0	-1	14	23	-95	-2	0
6	0	0	2	2	-2	-29	7
7	0	-1	5	2	17	-54	-14
8	0	0	-1	-4	-3	-47	82
9	0	0	3	1	9	62	53

FILE 23. Listing of TEST_ORIG.UNV

```

-1
55
NONE
NONE
NONE
NONE
  33    2    12    13
  1    2    2    12    2    3
  2    4    0    1
3.90901E+00 4.51733E+02 8.08673E-04 0.00000E+00
  1
0.00000E+00 6.05988E-04 2.90844E-03
  2
0.00000E+00 1.46372E-02 1.10035E-02
  3
0.00000E+00 2.32369E-03 -3.22137E-03
  4
0.00000E+00 7.25754E-03 4.58817E-03
  5
0.00000E+00 3.97546E-02 5.27876E-02
  6
0.00000E+00 3.71753E-02 3.80735E-02
  7
0.00000E+00 2.72621E-02 4.69676E-02
  8
0.00000E+00 4.00515E-02 5.04985E-02
  9
0.00000E+00 7.36587E-02 8.98097E-02
 10
0.00000E+00 8.44366E-02 8.10007E-02
 11
0.00000E+00 7.86361E-02 9.22585E-02
 12
0.00000E+00 7.63707E-02 7.70751E-02
 13
0.00000E+00 1.77802E-01 1.64980E-01
 14
0.00000E+00 1.63436E-01 2.43131E-01
 15
0.00000E+00 1.74143E-01 1.98065E-01
 16
0.00000E+00 1.60286E-01 1.85348E-01
 17
0.00000E+00 2.62029E-01 2.85119E-01
 18
0.00000E+00 2.10558E-01 3.12275E-01
 19
0.00000E+00 2.56983E-01 2.72729E-01
 20
0.00000E+00 2.60810E-01 2.81446E-01
 21
9.59189E-02 3.52018E-01 4.58568E-01
 22
-2.42932E-02 3.52404E-01 4.95502E-01
 23
-1.42126E-01 4.04253E-01 4.13553E-01
 24
3.26669E-02 3.87585E-01 4.50759E-01
 25

```

File 23.

0.00000E+00 5.02115E-01 6.01115E-01
 26
 0.00000E+00 4.94801E-01 5.45924E-01
 27
 0.00000E+00 5.22141E-01 5.62843E-01
 28
 0.00000E+00 4.78459E-01 5.49035E-01
 29
 0.00000E+00 6.26400E-01 7.20207E-01
 30
 0.00000E+00 6.55085E-01 7.09896E-01
 31
 0.00000E+00 6.44776E-01 7.32553E-01
 32
 0.00000E+00 6.23617E-01 7.16556E-01
 33
 1.55381E-01 7.30608E-01 8.95908E-01
 34
 0.00000E+00 7.46651E-01 8.71607E-01
 35
 -1.30737E-01 7.55347E-01 8.96688E-01
 36
 0.00000E+00 8.52956E-01 9.34047E-01
 37
 0.00000E+00 8.74632E-01 1.17069E+00
 38
 0.00000E+00 8.35688E-01 1.05967E+00
 39
 0.00000E+00 8.95196E-01 1.02448E+00
 40
 0.00000E+00 9.34785E-01 1.04290E+00
 41
 9.81353E-02 1.15422E+00 1.33781E+00
 42
 3.98632E-02 1.04639E+00 1.30437E+00
 43
 -1.63369E-01 1.17483E+00 1.38548E+00
 44
 3.06369E-02 1.14973E+00 1.28467E+00
 -1
 -1
 55
 NONE
 NONE
 NONE
 NONE
 33 2 12 13
 1 2 2 12 2 3
 2 4 0 2
 3.97665E+00 1.14532E+03 5.37419E-04 0.00000E+00
 1
 0.00000E+00 1.04765E-03 -2.32200E-02
 2
 0.00000E+00 -3.98608E-03 4.52396E-02
 3
 0.00000E+00 -1.07744E-02 -2.70677E-03
 4
 0.00000E+00 4.69239E-02 3.21980E-03
 5
 0.00000E+00 1.23949E-02 1.25289E-02
 6
 0.00000E+00 -1.91165E-02 -1.86815E-02
 7

File 23. (cont.)

0.00000E+00 -9.32850E-03 -2.61823E-02
 8
 0.00000E+00 -9.97006E-03 9.17283E-03
 9
 0.00000E+00 1.47810E-01 -1.09791E-01
 10
 0.00000E+00 1.36209E-01 -1.54689E-01
 11
 0.00000E+00 7.32647E-02 -1.06356E-01
 12
 0.00000E+00 1.16417E-01 -1.43167E-01
 13
 0.00000E+00 2.15392E-01 -2.59829E-01
 14
 0.00000E+00 2.32233E-01 -2.54967E-01
 15
 0.00000E+00 2.52930E-01 -1.48849E-01
 16
 0.00000E+00 2.28479E-01 -2.55565E-01
 17
 0.00000E+00 4.16543E-01 -4.80167E-01
 18
 0.00000E+00 3.79088E-01 -3.99520E-01
 19
 0.00000E+00 4.06304E-01 -4.12648E-01
 20
 0.00000E+00 4.66934E-01 -4.48781E-01
 21
 5.97803E-02 6.16944E-01 -3.73739E-01
 22
 2.11626E-01 6.06407E-01 -3.58789E-01
 23
 -1.45549E-02 6.49873E-01 -4.53493E-01
 24
 -1.71616E-01 5.47113E-01 -4.81807E-01
 25
 0.00000E+00 7.61613E-01 -6.49526E-01
 26
 0.00000E+00 8.39977E-01 -8.01377E-01
 27
 0.00000E+00 7.61650E-01 -8.87323E-01
 28
 0.00000E+00 8.31542E-01 -8.93342E-01
 29
 0.00000E+00 1.06211E+00 -1.14569E+00
 30
 0.00000E+00 1.01481E+00 -1.06296E+00
 31
 0.00000E+00 9.96015E-01 -1.10278E+00
 32
 0.00000E+00 1.02254E+00 -1.14745E+00
 33
 -2.61382E-03 1.23103E+00 -1.10961E+00
 34
 0.00000E+00 1.30161E+00 -1.36636E+00
 35
 -5.08692E-02 1.25538E+00 -1.16624E+00
 36
 0.00000E+00 1.20025E+00 -1.12043E+00
 37
 0.00000E+00 1.36889E+00 -1.46030E+00
 38
 0.00000E+00 1.46821E+00 -1.35390E+00

File 23. (cont.)

39
 0.00000E+00 1.55369E+00 -1.46922E+00
 40
 0.00000E+00 1.47302E+00 -1.62463E+00
 41
 1.42426E-01 1.96961E+00 -1.79585E+00
 42
 3.33163E-01 1.78586E+00 -1.73646E+00
 43
 -5.66661E-02 1.92485E+00 -2.03713E+00
 44
 -3.59747E-01 1.85784E+00 -2.02265E+00
 -1

.
 .
 .
 .
 .
 .
 .
 .
 .
 .

FILE 24. Listing of UNVRNM.INP

21 21
22 22
23 23
24 24
45 45
46 46
47 47
48 48

File 25. Listing of TEST.UNV

```

-1
55
NONE
NONE
NONE
NONE
  33    2    12    13
    1    2    2    12    2    3
    2    4    0    1
3.90901E+00 4.51733E+02 8.08673E-04 0.00000E+00
  1
0.00000E+00 6.05988E-04 2.90844E-03
  2
0.00000E+00 1.46372E-02 1.10035E-02
  3
0.00000E+00 2.32369E-03 -3.22137E-03
  4
0.00000E+00 7.25754E-03 4.58817E-03
  5
0.00000E+00 3.97546E-02 5.27876E-02
  6
0.00000E+00 3.71753E-02 3.80735E-02
  7
0.00000E+00 2.72621E-02 4.69676E-02
  8
0.00000E+00 4.00515E-02 5.04985E-02
  9
0.00000E+00 7.36587E-02 8.98097E-02
 10
0.00000E+00 8.44366E-02 8.10007E-02
 11
0.00000E+00 7.86361E-02 9.22585E-02
 12
0.00000E+00 7.63707E-02 7.70751E-02
 13
0.00000E+00 1.77802E-01 1.64980E-01
 14
0.00000E+00 1.63436E-01 2.43131E-01
 15
0.00000E+00 1.74143E-01 1.98065E-01
 16
0.00000E+00 1.60286E-01 1.85348E-01
 17
0.00000E+00 2.62029E-01 2.85119E-01
 18
0.00000E+00 2.10558E-01 3.12275E-01
 19
0.00000E+00 2.56983E-01 2.72729E-01
 20
0.00000E+00 2.60810E-01 2.81446E-01
 21
9.59189E-02 3.52018E-01 4.58568E-01
 22
-2.42932E-02 3.52404E-01 4.95502E-01
 23
-1.42126E-01 4.04253E-01 4.13553E-01
 24
3.26669E-02 3.87585E-01 4.50759E-01
 25
0.00000E+00 5.02115E-01 6.01115E-01
 26

```

File 25.

0.00000E+00 4.94801E-01 5.45924E-01
 27
 0.00000E+00 5.22141E-01 5.62843E-01
 28
 0.00000E+00 4.78459E-01 5.49035E-01
 29
 0.00000E+00 6.26400E-01 7.20207E-01
 30
 0.00000E+00 6.55085E-01 7.09896E-01
 31
 0.00000E+00 6.44776E-01 7.32553E-01
 32
 0.00000E+00 6.23617E-01 7.16556E-01
 33
 1.55381E-01 7.30608E-01 8.95908E-01
 34
 0.00000E+00 7.46651E-01 8.71607E-01
 35
 -1.30737E-01 7.55347E-01 8.96688E-01
 36
 0.00000E+00 8.52956E-01 9.34047E-01
 37
 0.00000E+00 8.74632E-01 1.17069E+00
 38
 0.00000E+00 8.35688E-01 1.05967E+00
 39
 0.00000E+00 8.95196E-01 1.02448E+00
 40
 0.00000E+00 9.34785E-01 1.04290E+00
 41
 9.81353E-02 1.15422E+00 1.33781E+00
 42
 3.98632E-02 1.04639E+00 1.30437E+00
 43
 -1.63369E-01 1.17483E+00 1.38548E+00
 44
 3.06369E-02 1.14973E+00 1.28467E+00
 -1
 -1
 55
 NONE
 NONE
 NONE
 NONE
 33 2 12 13
 1 2 2 12 2 3
 2 4 0 2
 3.97665E+00 1.14532E+03 5.37419E-04 0.00000E+00
 1
 0.00000E+00 1.04765E-03 -2.32200E-02
 2
 0.00000E+00 -3.98608E-03 4.52396E-02
 3
 0.00000E+00 -1.07744E-02 -2.70677E-03
 4
 0.00000E+00 4.69239E-02 3.21980E-03
 5
 0.00000E+00 1.23949E-02 1.25289E-02
 6
 0.00000E+00 -1.91165E-02 -1.86815E-02
 7
 0.00000E+00 -9.32850E-03 -2.61823E-02
 8

File 25. (cont.)

III-XXIX
C-2

0.00000E+00 -9.97006E-03 9.17283E-03
9
0.00000E+00 1.47810E-01 -1.09791E-01
10
0.00000E+00 1.36909E-01 -1.54689E-01
11
0.00000E+00 7.32647E-02 -1.06356E-01
12
0.00000E+00 1.16417E-01 -1.43167E-01
13
0.00000E+00 2.15392E-01 -2.59829E-01
14
0.00000E+00 2.32233E-01 -2.54967E-01
15
0.00000E+00 2.52930E-01 -1.48849E-01
16
0.00000E+00 2.28479E-01 -2.55565E-01
17
0.00000E+00 4.16543E-01 -4.80167E-01
18
0.00000E+00 3.79088E-01 -3.99520E-01

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File 25. (cont.)

III-XXX

FILE 26. Listing of GRIDS.BLK

```
$-----
$BULK DATA DECK FOLLOWS
$-----
$
$GRAVITY LOAD IN +Z
$GRAV,103,,386.1,0.0,0.0,1.0
$GRAVITY LOAD IN -Y
$GRAV,103,,386.1,0.0,-1.0,0.0
$
$-----
$
$PROPERTIES FOR TIP PLATE CONNECTING STRUTS
$
PBAR,101,103,1.0,1.0,1.0,1.0
MAT1,103,10.E9,,.3,.000001
$
$PROPERTIES FOR LONGERONS AND DIAGONALS
$
PROD,201,102,,1139,.0169
PROD,202,204,,1139,.0169
MAT1,102,10.E6,,.3,.0001894
MAT1,111,10.E6,,.3,.0002591
MAT1,112,30.E6,,.3,.0007513
MAT1,204,10.E6,,.3,.0002034
$
$TIP PLATE ELEMENTS
$
cquad4,401,501,45,52,56,54,0.
cquad4,402,501,52,56,58,50,0.
cquad4,403,501,50,58,60,48,0.
cquad4,404,501,58,60,62,64,0.
cquad4,405,501,58,64,66,56,0.
cquad4,406,501,56,66,68,54,0.
cquad4,407,501,46,70,66,68,0.
cquad4,408,501,70,72,64,66,0.
cquad4,409,501,72,47,62,64,0.
cquad4,420,502,45,52,56,54,0.
cquad4,421,502,52,56,58,50,0.
cquad4,422,502,50,58,60,48,0.
cquad4,423,502,58,60,62,64,0.
cquad4,424,502,58,64,66,56,0.
cquad4,425,502,56,66,68,54,0.
cquad4,426,502,46,70,66,68,0.
cquad4,427,502,70,72,64,66,0.
cquad4,428,502,72,47,62,64,0.
pshell,501,111,.375,111
pshell,502,112,.5,112
$
$CANTILEVERED BOUNDARY CONDITIONS
$
SPC1,20,123456,1,2,3,4
$
$TRUSS GRID POINTS
$
GRID,1,,0.,0.,0.
GRID,2,,0.,0.000,19.700
GRID,3,,0.,19.7,19.7
GRID,4,,0.,19.700,0.000
GRID,5,,19.7,0.,0.
GRID,6,,19.7,0.000,19.700
```

File 26.

III-XXXI

GRID,7,,19.7,19.7,19.7
 GRID,8,,19.7,19.700,0.000
 GRID,9,,39.4,0.,0.
 GRID,10,,39.4,0.000,19.700
 GRID,11,,39.4,19.7,19.7
 GRID,12,,39.4,19.700,0.000
 GRID,13,,59.1,0.,0.
 GRID,14,,59.1,0.000,19.700
 GRID,15,,59.1,19.7,19.7
 GRID,16,,59.1,19.700,0.000
 GRID,17,,78.8,0.,0.
 GRID,18,,78.8,0.000,19.700
 GRID,19,,78.8,19.7,19.7
 GRID,20,,78.8,19.700,0.000
 GRID,21,,98.5,0.,0.
 GRID,22,,98.5,0.000,19.700
 GRID,23,,98.5,19.7,19.7
 GRID,24,,98.5,19.700,0.000
 GRID,25,,118.2,0.,0.
 GRID,26,,118.2,0.000,19.700
 GRID,27,,118.2,19.7,19.7
 GRID,28,,118.2,19.700,0.000
 GRID,29,,137.9,0.,0.
 GRID,30,,137.9,0.000,19.700
 GRID,31,,137.9,19.7,19.7
 GRID,32,,137.9,19.700,0.000
 GRID,33,,157.6,0.,0.
 GRID,34,,157.6,0.000,19.700
 GRID,35,,157.6,19.7,19.7
 GRID,36,,157.6,19.700,0.000
 GRID,37,,177.3,0.,0.
 GRID,38,,177.3,0.000,19.700
 GRID,39,,177.3,19.7,19.7
 GRID,40,,177.3,19.700,0.000
 GRID,41,,197.0,0.,0.
 GRID,42,,197.0,0.000,19.700
 GRID,43,,197.0,19.7,19.7
 GRID,44,,197.0,19.700,0.000
 GRID,45,,198.125,0.,0.
 GRID,46,,198.125,0.000,19.700
 GRID,47,,198.125,19.7,19.7
 GRID,48,,198.125,19.700,0.000
 \$
 \$PLATE GRID POINTS
 \$
 GRID,52,,198.125,6.567,0.000
 GRID,50,,198.125,13.134,0.000
 GRID,54,,198.125,0.000,6.567
 GRID,56,,198.125,6.567,6.567
 GRID,58,,198.125,13.134,6.567
 GRID,60,,198.125,19.700,6.567
 GRID,62,,198.125,19.700,13.134
 GRID,64,,198.125,13.134,13.134
 GRID,66,,198.125,6.567,13.134
 GRID,68,,198.125,0.000,13.134
 GRID,70,,198.125,6.567,19.700
 GRID,72,,198.125,13.134,19.700
 \$
 \$TRUSS ELEMENTS
 \$
 CROD,1,201,1,2
 CROD,2,201,2,3
 CROD,3,201,3,4

File 26. (cont.)

CROD,4,201,1,4
CROD,5,201,5,6
CROD,6,201,6,7
CROD,7,201,7,8
CROD,8,201,5,8
CROD,9,201,1,5
CROD,10,201,2,6
CROD,11,201,3,7
CROD,12,201,4,8
CROD,13,202,2,4
CROD,14,202,2,7
CROD,15,202,6,8
CROD,16,202,4,5
CROD,17,202,4,7
CROD,18,202,2,5
CROD,19,201,6,10
CROD,20,201,9,10
CROD,21,201,5,9
CROD,22,201,7,11
CROD,23,201,8,12
CROD,24,201,11,12
CROD,25,201,10,11
CROD,26,201,9,12
CROD,27,202,5,10
CROD,28,202,7,12
CROD,29,202,7,10
CROD,30,202,10,12
CROD,31,202,5,12
CROD,32,201,10,14
CROD,33,201,9,13
CROD,34,201,13,14
CROD,35,201,11,15
CROD,36,201,12,16
CROD,37,201,15,16
CROD,38,201,14,15
CROD,39,201,13,16
CROD,40,202,10,13
CROD,41,202,12,15
CROD,42,202,10,15
CROD,43,202,12,13
CROD,44,202,14,16
CROD,45,201,14,18
CROD,46,201,13,17
CROD,47,201,17,18
CROD,48,201,15,19
CROD,49,201,16,20
CROD,50,201,19,20
CROD,51,201,18,19
CROD,52,201,17,20
CROD,53,202,13,18
CROD,54,202,15,20
CROD,55,202,15,18
CROD,56,202,13,20
CROD,57,202,18,20
CROD,58,201,18,22
CROD,59,201,17,21
CROD,60,201,19,23
CROD,61,201,20,24
CROD,62,201,23,24
CROD,63,201,22,23
CROD,64,201,21,24
CROD,65,201,21,22
CROD,66,202,18,21

File 26. (cont.)

CROD,67,202,20,23
CROD,68,202,18,23
CROD,69,202,20,21
CROD,70,202,22,24
CROD,71,201,22,26
CROD,72,201,21,25
CROD,73,201,25,26
CROD,74,201,23,27
CROD,75,201,24,28
CROD,76,201,26,27
CROD,77,201,27,28
CROD,78,201,25,28
CROD,79,202,21,26
CROD,80,202,23,26
CROD,81,202,21,28
CROD,82,202,23,28
CROD,83,202,26,28
CROD,84,201,26,30
CROD,85,201,25,29
CROD,86,201,30,31
CROD,87,201,31,32
CROD,88,201,29,32
CROD,89,201,29,30
CROD,90,201,27,31
CROD,91,201,28,32
CROD,92,202,26,29
CROD,93,202,26,31
CROD,94,202,28,29
CROD,95,202,28,31
CROD,96,202,30,32
CROD,97,201,29,33
CROD,98,201,30,34
CROD,99,201,34,35
CROD,100,201,33,34
CROD,101,201,35,36
CROD,102,201,33,36
CROD,103,201,32,36
CROD,104,201,31,35
CROD,105,202,29,34
CROD,106,202,31,34
CROD,107,202,29,36
CROD,108,202,31,36
CROD,109,202,34,36
CROD,110,201,33,37
CROD,111,201,34,38
CROD,112,201,36,40
CROD,113,201,35,39
CROD,114,201,37,40
CROD,115,201,37,38
CROD,116,201,38,39
CROD,117,201,39,40
CROD,118,202,34,37
CROD,119,202,36,39
CROD,120,202,34,39
CROD,121,202,36,37
CROD,122,202,38,40
CROD,123,201,37,41
CROD,124,201,38,42
CROD,125,201,40,44
CROD,126,201,39,43
CROD,127,201,41,44
CROD,128,201,41,42
CROD,129,201,42,43

File 26. (cont.)

CROD,130,201,43,44
 CROD,131,202,37,42
 CROD,132,202,39,44
 CROD,133,202,39,42
 CROD,134,202,37,44
 CROD,135,202,42,44
 \$
 \$CONNECTING STRUT ELEMENTS
 \$
 CBAR,136,101,44,48,0.,0.,1.,1
 CBAR,137,101,43,47,0.,0.,1.,1
 CBAR,138,101,42,46,0.,0.,1.,1
 CBAR,139,101,41,45,0.,0.,1.,1
 \$
 \$CONM2'S FOR JOINT MASSES
 \$ ADD MASS FOR ACCELS AND CABLING
 \$
 CONM2,301,1,..001821
 CONM2,302,2,..002917
 CONM2,303,3,..001821
 CONM2,304,4,..002917
 CONM2,305,5,..003648
 CONM2,306,6,..002551
 CONM2,307,7,..003648
 CONM2,308,8,..002551
 CONM2,309,9,..002186
 CONM2,310,10,..004013
 CONM2,311,11,..002186
 CONM2,312,12,..004013
 CONM2,313,13,..003648
 CONM2,314,14,..002551
 CONM2,315,15,..003648
 CONM2,316,16,..002551
 CONM2,317,17,..002186
 CONM2,318,18,..004013
 CONM2,319,19,..002186
 CONM2,320,20,..004013
 CONM2,321,21,..003648
 CONM2,322,22,..002551
 CONM2,323,23,..003648
 CONM2,324,24,..002551
 CONM2,325,25,..002186
 CONM2,326,26,..004013
 CONM2,327,27,..002186
 CONM2,328,28,..004013
 CONM2,329,29,..003648
 CONM2,330,30,..002551
 CONM2,331,31,..003648
 CONM2,332,32,..002551
 CONM2,333,33,..002186
 CONM2,334,34,..004013
 CONM2,335,35,..002186
 CONM2,336,36,..004013
 CONM2,337,37,..003648
 CONM2,338,38,..002551
 CONM2,339,39,..003648
 CONM2,340,40,..002551
 CONM2,341,41,..001821
 CONM2,342,42,..002917
 CONM2,343,43,..001821
 CONM2,344,44,..002917
 CONM2,345,45,..0009719
 CONM2,346,46,..0009719

File 26. (cont.)

CONM2,347,47,,.0009719
CONM2,348,48,,.0009719
CONM2,350,50,,.000832
CONM2,352,52,,.000832
CONM2,354,54,,.000832
CONM2,360,60,,.000832
CONM2,362,62,,.000832
CONM2,368,68,,.000832
CONM2,370,70,,.000832
CONM2,372,72,,.000832
\$END OF BULK DATA

File 26. (cont.)

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FILE 27. Listing of TEST.DMI

```

$
DMIG PHIG 0 9 1 0 9
$
DMIG PHIG 1 0 1 2 6.060-4
1 3 2.908-3 2 2 0.01464
2 3 0.01100 3 2 2.324-3
3 3 3.221-3 4 2 7.258-3
4 3 4.588-3 5 2 0.03975
5 3 0.05279 6 2 0.03718
6 3 0.03807 7 2 0.02726
7 3 0.04697 8 2 0.04005
8 3 0.05050 9 2 0.07366
9 3 0.08981 10 2 0.08444
10 3 0.08100 11 2 0.07864
11 3 0.09226 12 2 0.07637
12 3 0.07708 13 2 0.17780
13 3 0.16498 14 2 0.16344
14 3 0.24313 15 2 0.17414
15 3 0.19806 16 2 0.16029
16 3 0.18535 17 2 0.26203
17 3 0.28512 18 2 0.21056
18 3 0.31227 19 2 0.25698
19 3 0.27273 20 2 0.26081
20 3 0.28145 21 1 0.09592
21 2 0.35202 21 3 0.45857
22 1 0.02429 22 2 0.35240
22 3 0.49550 23 1 0.14213
23 2 0.40425 23 3 0.41355
24 1 0.03267 24 2 0.38759
24 3 0.45076 25 2 0.50212
25 3 0.60111 26 2 0.49480
26 3 0.54592 27 2 0.52214
27 3 0.56284 28 2 0.47846
28 3 0.54904 29 2 0.62640
29 3 0.72021 30 2 0.65509
30 3 0.70990 31 2 0.64478
31 3 0.73255 32 2 0.62362
32 3 0.71656 33 1 0.15538
33 2 0.73061 33 3 0.89591
34 2 0.74665 34 3 0.87161
35 1 0.13074 35 2 0.75535
35 3 0.89669 36 2 0.85296
36 3 0.93405 37 2 0.87463
37 3 1.17069 38 2 0.83569
38 3 1.05967 39 2 0.89520
39 3 1.02448 40 2 0.93479
40 3 1.04290 41 1 0.09814
41 2 1.15422 41 3 1.33781
42 1 0.03986 42 2 1.04639
42 3 1.30437 43 1 0.16337
43 2 1.17483 43 3 1.38548
44 1 0.03064 44 2 1.14973
44 3 1.28467

$
DMIG PHIG 2 0 1 2 1.048-3
1 3 0.02322 2 2 3.986-3
2 3 0.04524 3 2 0.01077
3 3 2.707-3 4 2 0.04692
4 3 3.220-3 5 2 0.01239
5 3 0.01253 6 2 0.01912

```

File 27.

6	3-0.01868	7	2-9.329-3
7	3-0.02618	8	2-9.970-3
8	3-9.173-3	9	2-0.14781
9	3-0.10979	10	2-0.13691
10	3-0.15469	11	2-0.07326
11	3-0.10636	12	2-0.11642
12	3-0.14317	13	2-0.21539
13	3-0.25983	14	2-0.23223
14	3-0.25497	15	2-0.25293
15	3-0.14885	16	2-0.22848
16	3-0.25556	17	2-0.41654
17	3-0.48017	18	2-0.37909
18	3-0.39952	19	2-0.40630
19	3-0.41265	20	2-0.46693
20	3-0.44878	21	1-0.05978
21	2-0.61694	21	3-0.37374
22	1-0.21163	22	2-0.60641
22	3-0.35879	23	1-0.01455
23	2-0.64987	23	3-0.45349
24	1-0.17162	24	2-0.54711
24	3-0.48181	25	2-0.76161
25	3-0.64953	26	2-0.83998
26	3-0.80138	27	2-0.76165
27	3-0.88732	28	2-0.83154
28	3-0.89334	29	2-1.06211
29	3-1.14569	30	2-1.01481
30	3-1.06296	31	2-0.99602
31	3-1.10278	32	2-1.02254
32	3-1.14745	33	1-2.614-3
33	2-1.23103	33	3-1.10961
34	2-1.30161	34	3-1.36636
35	1-0.05087	35	2-1.25538
35	3-1.16624	36	2-1.20025
36	3-1.12043	37	2-1.36889
37	3-1.46030	38	2-1.46821
38	3-1.35390	39	2-1.55369
39	3-1.46922	40	2-1.47302
40	3-1.62463	41	1-0.14243
41	2-1.96961	41	3-1.79585
42	1-0.33316	42	2-1.78586
42	3-1.73646	43	1-0.05667
43	2-1.92485	43	3-2.03713
44	1-0.35975	44	2-1.85784
44	3-2.02265		

File 27. (cont.)

III-XXXVIII

FILE 28. Listing of PHIA TEST.DAT

```
1.    NASTRAN DBSET 15 = (DB02)
2.    ID   PHIA,TEST
3.    $
4.    $ DB01 = TEST MODES DATA BASE
5.    $ DB02 = TAM DATA BASE (READ ONLY)
6.    $
7.    TIME 600 $ 600 CPU MINUTES (VAX 11/780 TIMING)
8.    DIAG 8  $ PRINT MATRIX TRAILERS
9.    DIAG 20 $ PRINT DATA BASE FETCH/STORE MESSAGES
10.   $
11.   $ CREATE TEST MODE DATA BLOCKS
12.   $
13.   &PHIA TEST.DMP
14.   $
15.   CEND
16.   TITLE = CONVERT TEST MODE DATA TO NASTRAN FORMAT (OUTPUT4)
17.   $
18.   ECHO = NONE
19.   $
20.   BEGIN BULK
21.   $
22.   PARAM EXTSORT 0
23.   PARAM NORMTEST 0
24.   $
25.   $ TEST DATA IN DMI FORMAT (FROM UNVDMI)
26.   $
27.   &TEST.DMI
28.   $
29.   ENDDATA
```

FILE 29. Listing of PHIA TEST.COM

```
1.      $!  
2.      $! DATABASE WITH TEST DATA  
3.      $ ASSIGN PHIA TEST.D01 DB01 ! OUTPUT  
4.      $!  
5.      $! TAM DATABASE (READ ONLY)  
6.      $ ASSIGN TENBAY14.D01 DB02 ! INPUT  
7.      $!  
8.      $! OUTPUT: TEST MODES IN OUTPUT4 FORMAT  
9.      $ ASSIGN TEST.OP4 FOR011 ! OUTPUT  
10.     $!
```

FILE 30. Listing of CORL8_TAM_TEST.DAT

```
ID   TAM,XCORL8_TAM_TEST
$
$   CORRELATING TAM & TEST MODELS
$
$   USER ASSIGNED FILES:
$   -----
$   FOR011 = TAM MASS MATRIX: OUTPUT4 FILE (BCD FORMAT)
$   FOR012 = TAM MODE SHAPES: OUTPUT4 FILE (BCD FORMAT)
$   FOR013 = TEST MODE SHAPES: OUTPUT4 FILE (BCD FORMAT)
$
TIME 60   $ 60 CPU MINUTES (VAX 11/750 TIMING)
DIAG 8    $ PRINT MATRIX TRAILERS
DIAG 20   $ PRINT DATA BASE FETCH/STORE MESSAGES
$
$ PERFORM TEST/TAM CORRELATION
$ -----
$ REPLACE THE NEXT LINE WITH THE DMAP CORL8X.DMP
$
&IMAT2$DUB0:[JAVEED.LANGLEY.SOFTWARE]CORL8X.DMP
$
CEND
$
TITLE = 14 DOFS TEST CONFIGURATION
SUBTITLE = CORRELATE TAM TO TEST
$
ECHO= NONE
$
BEGIN BULK
$
PARAM,ORTHO,1      $ PERFORM ORTHOGONALITY CHECK
$
PARAM,CROSS,1      $ PERFORM CROSS-ORTHOGONALITY CHECK
$
PARAM,MAC,1        $ DO PERFORM MAC CALCULATION
$
PARAM,MASS,1       $ TAM MASS MATRIX IS PRESENT
$
PARAM,NORMTAM,-1   $ DO NOT RENORMALIZE TAM MODE SHAPES
$
PARAM,NORMTEST,1   $ RENORMALIZE TEST MODE SHAPES
$
ENDDATA
```

FILE 31. Listing of CORL8_TAM_TEST.COM

```
$ | ASSIGNMENT FILES CORRELATING TAM & FEM MODELS
$ |
$ | TAM MASS MATRIX
$ |
$ | ASSIGN [PEM.14EXAMP]TAMMASS14.OP4 FOR011 | |
$ |
$ | TAM MODE SHAPES
$ |
$ | ASSIGN [PEM.14EXAMP]TAMMODES14.OP4 FOR012 | |
$ |
$ | FEM MODES (PARTITIONED TO TAM DOF)
$ |
$ | ASSIGN [PEM.14EXAMP]TEST.OP4 FOR013 | |
$ |
```

FILE 32. Listing of CORL8_I_TAM_TEST.OUT

1 14 DOFS TEST CONFIGURATION
CORRELATE IRS TAM TO FEM

INTERMEDIATE MATRIX ... ORTHO

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	0	0
2	0	100	0	0	0	1	0	5	14
3	0	0	100	0	0	0	-1	-1	-1
4	0	0	0	100	0	0	0	-2	-1
5	0	0	0	0	99	-1	1	-2	-12
6	0	1	0	0	-1	55	-1	-28	-43
7	0	0	-1	0	1	-1	95	0	1
8	9	5	-1	-2	-2	-28	0	35	16
9	-3	14	-1	-1	-12	-43	1	16	52

1 14 DOFS TEST CONFIGURATION
CORRELATE IRS TAM TO FEM

INTERMEDIATE MATRIX ... CROSSORT

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	9	-3
2	0	100	0	0	0	1	0	5	14
3	0	0	100	0	0	0	-1	-1	-1
4	0	0	0	-100	0	0	0	2	1
5	0	0	0	0	-100	1	-1	2	12
6	0	0	0	0	0	74	-2	-37	-57
7	0	0	0	0	0	0	97	-1	0
8	0	0	0	0	0	-1	0	45	-18
9	0	0	0	0	0	3	0	-7	-36

1 14 DOFS TEST CONFIGURATION
CORRELATE IRS TAM TO FEM

INTERMEDIATE MATRIX ... MACM

	1	2	3	4	5	6	7	8	9
1	100	0	0	0	0	0	0	49	3
2	0	100	0	0	0	0	0	5	27
3	0	0	100	0	2	0	2	0	2
4	0	0	0	100	0	15	0	51	0
5	0	0	2	0	100	15	7	0	75
6	0	0	0	7	9	96	0	4	7
7	0	0	1	0	7	0	100	0	6
8	41	0	1	51	13	1	1	81	18
9	0	22	0	2	77	8	6	4	93

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13. ABSTRACT (Maximum 200 words) The primary objective of structural analysis for aerospace applications is to obtain a verified finite element model (FEM). The verified FEM can be used for loads analysis, evaluate structural modifications, or design control systems. Verification of the FEM is generally obtained as the result of correlating test and FEM models. A Test-Analysis Model (TAM) is very useful in the correlation process. A TAM is essentially a FEM reduced to the size of the test model, which attempts to preserve the dynamic characteristics of the original FEM in the analysis range of interest. Numerous methods for generating TAMs have been developed and presented in the literature. The major emphasis of this paper is a description of the procedures necessary for creation of the TAM and the correlation of the reduced models with the FEM or with test results. Herein, three methods are discussed, namely Guyan, Improved Reduced System (IRS), and Hybrid. Also included are the procedures for performing these analyses using MSC/NASTRAN. Finally, application of the TAM process is demonstrated with an experimental test configuration of a ten-bay cantilevered truss structure.				
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